# INTENSIVE EVALUATION AND MONITORING OF CHINOOK SALMON AND STEELHEAD TROUT PRODUCTION, CROOKED RIVER AND UPPER SALMON RIVER SITES

**Annual Progress Report 1990**

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**ABSTRACT**

Project 83-7 was established under the Northwest Power Planning Council's 1982 Fish and Wildlife Program, Measure 704 (d) (1) to monitor natural production of anadromous fish, evaluate Bonneville Power Administration habitat improvement projects, and develop a credit record for off-site mitigation projects in Idaho. Project 83-7 is divided into two sub-projects: general and intensive monitoring. Results of the intensive monitoring sub-project are reported here. Results from the general monitoring sub-project will be reported in a separate document (Scully et al. 1991, in progress).

The purpose of this intensive monitoring project is to determine the number of returning chinook and steelhead adults necessary to achieve optimal smolt production, and develop mitigation accounting based on increases in smolt production. Two locations are being intensively studied to meet these objectives. Information from this research will be applied to parr monitoring streams statewide to develop escapement objectives and determine success of habitat enhancement projects.

Field work began in 1987 in upper Salmon River and Crooked River (South Fork Clearwater River tributary). Methods include using weirs to trap adults, conducting ground and aerial redd counts, snorkeling to estimate parr populations, PIT-tagging juveniles to determine parr-to-smolt survival, trapping fall and spring downstream emigrants with scoop traps, and outplanting adults to determine juvenile carrying capacity. PIT tags also provide a wide range of other information such as migration timing, effects of flow and passage conditions on smolt survival, other factors affecting smolt survival, and growth.

Major findings of the project to date are:

1. Our data and data from the National Marine Fisheries Service shows that the peak period of arrival at Lower Granite Reservoir Dam for upper Snake River wild/natural spring chinook is later than the peak of the total spring chinook smolt run at Lower Granite Reservoir Dam. The data indicates this difference is a result of the earlier arrival of hatchery smolts which greatly outnumber the wild/natural smolts. This data also indicates that the current water budget, which is based upon when the greatest number of spring chinook smolts reach Lower Granite Reservoir Dam, may have actually delayed some of the wild/natural spring chinook stocks from Idaho in spring 1990.

2. Estimates of egg-to-parr survival rates from naturally-spawning spring chinook for the entire upper Salmon River averaged 4.8% (range 2.1% to 6.7%).

3. Estimates of egg-to-parr survival rates from natural spawners and adult outplants in the headwater streams of the upper Salmon River averaged 18.8% (range 8.5% to 32.0%).

4. With the brood year 1989 fish, we were able to make our first estimate of chinook egg-to-parr survival in Crooked River, and the results (15%) were similar to the average observed in other Idaho anadromous streams.

5. Run year 1988 to 1990 estimates of upper Salmon River parr-to-smolt survival to the head of Lower Granite Reservoir pool based on August PIT tagging ranged from 6.4% to 12.3% ($\bar{x}$= 9.5%) for chinook and 7.8% to 23.3% ($\bar{x}$ = 17.2%) for age 2+ and older steelhead. Run year 1989 and 1990 estimates of Crooked River parr-to-smolt survival to the head of Lower Granite Reservoir pool based on August PIT tagging were 5.2% and 5.7% for chinook and 33.5% and 14.1% for age 2+ and older steelhead, respectively.

6. For run year 1990, we estimated headwaters of the upper Salmon River spring chinook parr-to-smolt survival to the head of Lower Granite Reservoir pool from the following supplementation techniques to be: natural spawners (10.9%), adult outplants (8.5%), eyed eggs (7.3%), fry (5.7%), and summer parr (0.8%). The parr outplants may have had such a dismal survival as a result of a possible BKD outbreak made worse by being outplanted in warm weather.

7. Moderate fishing pressure combined with general fishing regulations (bait; no size limit) can result in the removal of a major portion of the age 2+ and older steelhead.

8. There may be a higher long-term PIT tag mortality in streams than has been observed in hatchery studies. If so, PIT tags are underestimating parr-to-smolt survival in the wild.

Other findings of this project are:

1. Our data indicates that in smaller spawning streams a total ground count just after the peak spawning time can accurately estimate chinook female escapement with an assumed female to redd ratio of 1:1.

2. Habitat improvement structures can provide clean gravel that attracts chinook spawners.

3. There may be a more natural component of the upper Salmon River chinook population that spawns higher up in the drainage than the more hatchery-influenced component.

4. Chinook and steelhead juveniles generally key in on the same stimuli for emigration, with storm events being the primary stimulus in the spring and sharp drops in water temperature being the primary stimulus in the fall.

5. Higher elevation (harsher climate) streams will have a higher percentage of parr emigrate in the fall with age 0 chinook and age 2+ and older steelhead emigrating at about the same percentage for a particular stream.

6. The Busterback and Alturas Lake Creek diversions block adult chinook from reaching the low gradient headwater streams where we have observed an average four times greater egg-to-parr survival than in the main river below these diversions.

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# INTRODUCTION

The purpose of this project is to quantify changes in chinook salmon Oncorhynchus tshawvtscha and steelhead trout O. mykiss smolt production relating to Bonneville Power Administration (BPA) funded habitat improvement projects. It is generally accepted that habitat improvement projects can increase fish production, and for anadromous populations, effectiveness is best measured by changes in smolt production. Actual increases in smolt production resulting from habitat projects have never been statistically quantified (Buell 1986). A realistic quantitative approach for Idaho is: 1) to estimate parr production attributable to habitat projects through general monitoring; 2) to quantify relationships between spawning escapement, parr production, and smolt production through intensive monitoring; and 3) to use the determined parr-to-smolt survival rates as a basis for BPA mitigation accounting.

The primary objectives of the intensive evaluation and monitoring portion of this project are to determine:

1. Smolt production from two anadromous stream reaches.

2. Parr-to-smolt survival rates for wild and natural chinook and steelhead for BPA habitat project mitigation.

3. The mathematical relationship between spawning escapement, parr production, and smolt production.

4. Migration characteristics of anadromous juveniles from the two study streams.

5. Habitat rearing potential, potential smolt production, and reproductive potential for the two study streams.

# STUDY AREAS

## Upper Salmon River

The Salmon River originates in the Sawtooth, Smokey, and White Cloud mountains in south central Idaho (Figure 1). The upper Salmon River (USR) study site is the entire Salmon River drainage upstream of the Sawtooth Hatchery weir at elevations above 1,980 m. Study sections are located throughout the upper basin. The river above Sawtooth Fish Hatchery is a major production area for spring chinook salmon and A-run summer steelhead trout. Resident salmonids in the USR drainage are native rainbow trout O. mykiss, cutthroat trout O. clarki, bull trout Salvelinus malma, mountain whitefish Prosopium williamsoni, and non-native brook trout S. fontinalis (Mallet 1974).

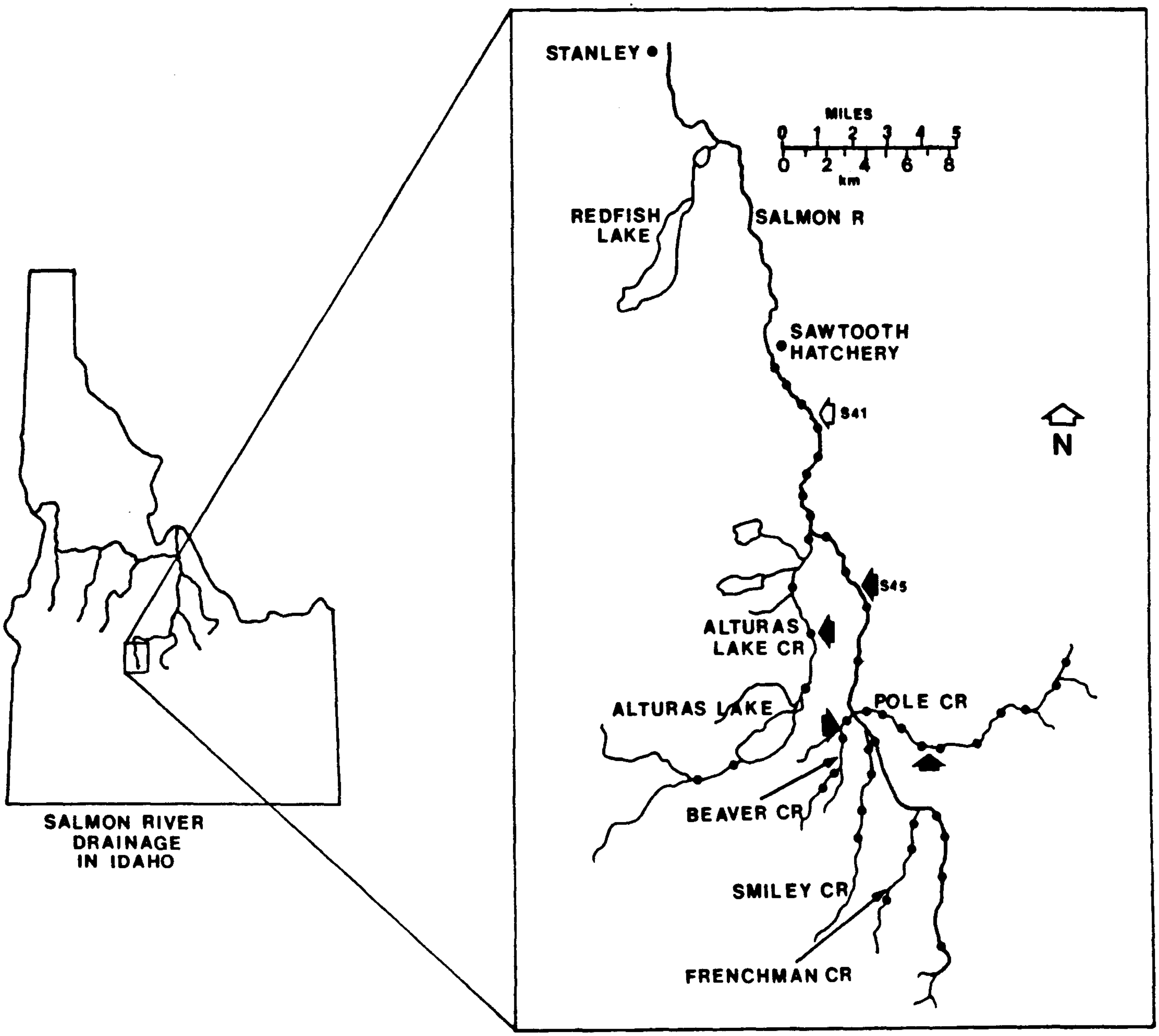


Figure 1. Location of the upper Salmon River study sections (•). Arrows indicate irrigation diversions with flow problems.

Historically, sockeye salmon O. nerka existed in all moraine lakes in the Stanley Basin (Everman 1895). An extremely depressed remnant run of sockeye returns to Redfish Lake, whose outlet enters the Salmon River approximately 2.7 km downstream from Sawtooth Hatchery. Adult sockeye occasionally have been seen in Alturas Lake Creek (K. Ball, Idaho Department of Fish and Game, personal communication), but an irrigation diversion that completely dewaters the creek every summer makes adult passage to the lake unlikely (Bowles and Cochnauer 1984). No other sockeye runs are known to exist in the Salmon River drainage.

Nearly pristine water quality and an abundance of high quality spawning gravel and rearing habitat is present throughout much of the upper basin. Water flows at the Sawtooth Hatchery range from lows of 1.73 to 3.46 $m^3/s$ from July through April to highs of 11.2 to 23.3 $m^3/s$ during May and June. Conductivity in the USR drainage ranges from 37 to 218 µmhos/cm (Emmett 1975).

Livestock grazing and hay production are predominant uses of private land throughout the USR basin. Grazing in riparian zones has degraded aquatic habitat in localized areas. Water diversions from the river and tributaries have impaired the potential for production of chinook and steelhead in some of the USR drainage.

Irrigation diversions in the USR have an adverse impact on river flows and fish passage. The Busterback diversion between Alturas Lake Creek and Pole Creek completely dewaters the river for approximately 3 km from July through September in an average flow year. Flow diversions from tributary streams vary from partial to complete dewatering. Conversion from flood to overhead sprinkler irrigation has decreased the withdrawal of water from Pole Creek since 1982. BPA funded the construction of a fish screen for the irrigation diversion on Pole Creek during 1983 to 1984. Steelhead fry have been outplanted into upper Pole Creek every year since 1985 (Idaho Department of Fish and Game, unpublished data). Chinook salmon had not been introduced into Pole Creek until supplementation research began with brood year 1988 fish.

The Sawtooth Fish Hatchery was constructed in cooperation with the U.S. Fish and Wildlife Service and the U.S. Army Corps of Engineers through the Lower Snake River Compensation Plan. The hatchery program involves trapping adult chinook and steelhead and releasing smolts and other life stages. The hatchery is designed to produce 2.4 million chinook smolts per year. Steelhead eyed eggs are sent to other facilities for rearing, and the smolts are transported back to Sawtooth Hatchery for release. The objective is to release 1.5 million steelhead smolts at Sawtooth Hatchery. At least 33% of the adult chinook and steelhead entering the trap are released upstream of the hatchery to spawn naturally.

## Crooked River

Crooked River (CR) originates at an elevation of 2,070 m in the Clearwater Mountains within the Nez Perce National Forest and enters the South Fork Clearwater River at river kilometer 94 at an elevation of 1,140 m (Figure 2).

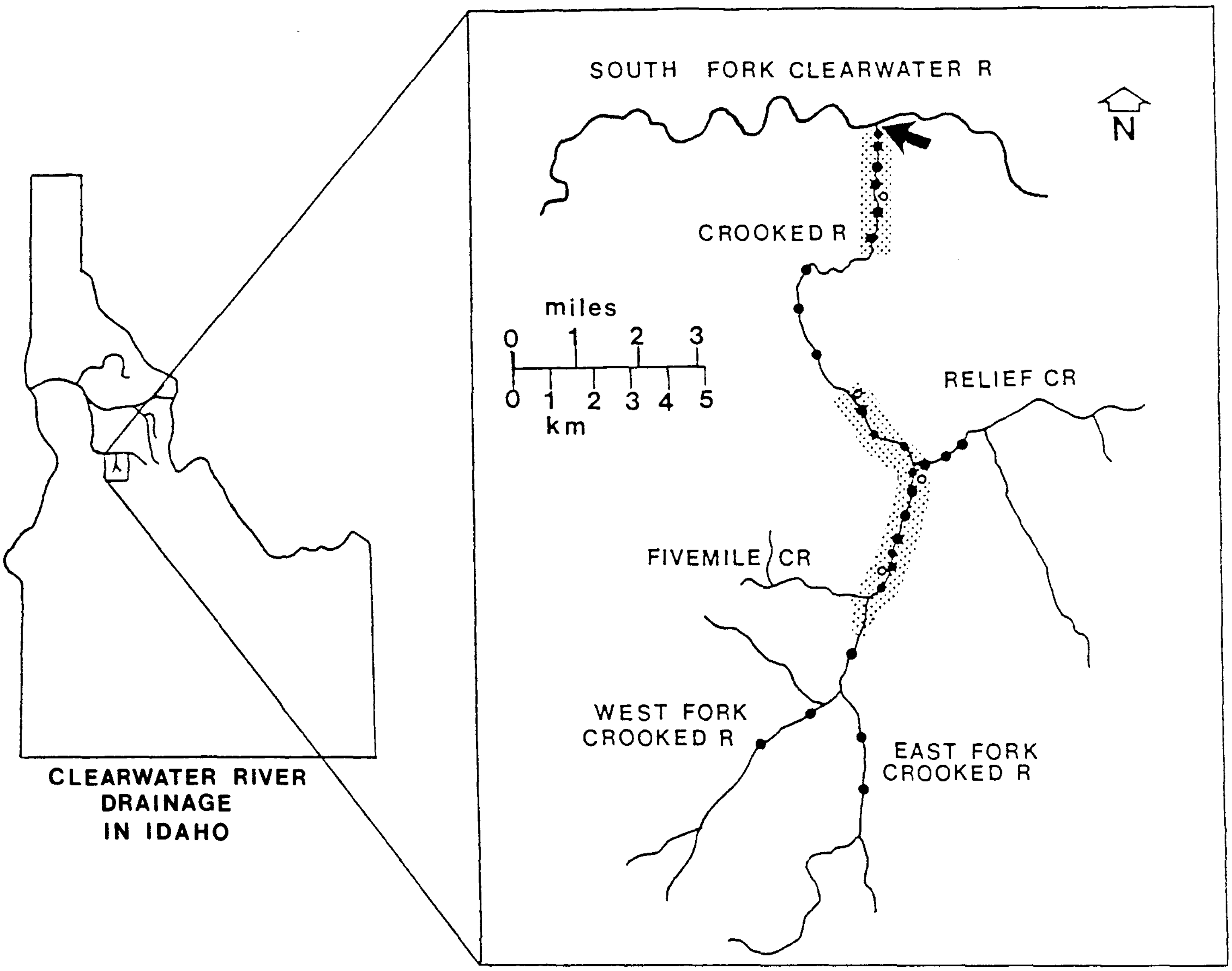


Figure 2. Location of the Crooked River study areas, pond (o) and river study sections (•), and meadows degraded by dredging (shaded). Arrow indicates location of trapping facility.

The study site includes the entire CR drainage. Historically, chinook and steelhead runs were eliminated by the construction of Harpster Dam on the South Fork Clearwater River in 1927. Spring chinook and B-run summer steelhead were reestablished in CR following removal of the dam in 1962. Resident salmonids in the CR drainage are native rainbow trout, cutthroat trout, bull trout, mountain whitefish, and non-native brook trout (Petrosky and Holubetz 1986). Flows on CR range from 4.3 to 0.2 $m^3/s$, and conductivity ranges from 35 to 50 μmhos/cm (Mann and Von Lindern 1987).

Dredge mining activities during the 1950s severely degraded habitat within the two meadow reaches of the stream. In the upstream meadow, the stream was forced to the outside of the floodplain resulting in a straight, high gradient channel. In the lower meadow, dredge tailings have forced the stream into long meanders with many ponds and sloughs. During runoff, juvenile trout and salmon use some of these ponds, but are trapped as flow recedes.

Fish density and habitat surveys were initiated in 1984 by the Idaho Department of Fish and Game (IDFG) and the Intermountain Forest and Range Experiment Station, U.S. Forest Service (USFS), Boise, Idaho. Petrosky and Holubetz (1985) found that densities of juvenile chinook and steelhead in the two meadow reaches were lower than in other Idaho streams. Densities of fish in the pools and high velocity sections were similar. Since chinook parr generally prefer pool habitat over high velocity sections, this lack of a relationship between juvenile density and habitat type indicates that the upper meadow reach was underseeded in 1984.

In 1984, the USFS, with BPA funds, placed a series of log structures, rock and boulder deflectors, organic debris structures, and loose rock weirs in the upper meadow in an effort to compensate for stream gradient and increase the pool to riffle ratio. In addition, banks were stabilized and revegetated, an off-channel pond was connected with a side channel, and a culvert blocking adult passage was removed (Hair and Stowell 1986). Recent efforts have concentrated on connecting additional ponds in the dredge tailings to the main channel and developing side channels to provide continuous water supply during low flow periods.

## METHODS

### Physical Habitat

Physical habitat surveys were conducted using the Idaho ocular method (Petrosky and Holubetz 1987) to help determine relationships between physical habitat and smolt production. In the USR study area, physical habitat surveys were conducted on 16 study sites. In the CR study area, physical habitat surveys were conducted on 11 study sites. The Idaho ocular method was derived from Platts et al. (1983). In this method, transects are established at 10-m intervals within each study section, and stream width is measured at each transect. Depth, velocity, substrate composition, embeddedness, and habitat type (i.e. pool, run, riffle, pocketwater, or backwater) as described by Shepard (1983) are measured or determined at the one-quarter, one-half, and three-quarter points of each stream transect. Proportions of sand (0 to 0.5 cm diameter), gravel (>0.5 to 7.4 cm), rubble (>7.5 to 30.4 cm), boulder (>30.4 cm), and bedrock that comprise the substrate are estimated visually. Embeddedness (the proportion of surface area of gravel, rubble, and boulder surrounded by sand) is classified in 5% intervals from 0% to 100%. Stream gradient is measured with a surveyor's transit and stadia rod as the elevation difference between the upper and lower section boundaries divided by the section length. Stream channel type is classified according to Rosgen (1985). All sections are flagged and photographed for future repeated measurements.

Project data have been entered into the IDFG physical habitat database for analysis. The management of this database is handled by the Idaho Habitat Evaluation for Off-Site Mitigation Record project and are reported in Scully et al. 1990.

## Adult Escapement and Redd Counts

Actual escapements for chinook and steelhead in the USR were obtained from Sawtooth Fish Hatchery records (Alsager 1990). Except for the possibility of a small percentage of early and late fish from each of the runs, the entire escapement above the hatchery weir consisted of fish that were collected in the hatchery trap and then released upstream to spawn naturally. Chinook escapement into CR was obtained from CR adult collection facility records (McGehee 1990). In CR, no adult escapement estimates for steelhead were available for 1990.

Chinook trend redd counts were conducted by regional fisheries personnel (Hassemer 1989). The trend count for the USR was a one-day peak count by helicopter during the first week in September that covered the entire current spawning area. The trend count for CR was not conducted in 1990 because we did not observe any redds in the trend count area during our ground count.

Total chinook redd counts were conducted by project personnel in both the USR and CR study areas by foot to determine natural spawning. Counts were done using guidelines identified by IDFG personnel (Redd Count Manual 1990), and data is reported in Hassemer (1989). The entire probable spawning area was walked to count redds and actively spawning fish. All encountered carcasses were measured (fork length) and cut open to confirm sex and completeness of spawning. The USR ground count was conducted from Sawtooth Hatchery to the headwaters on September 1 to 7, 1990. On CR, the ground count was conducted from the mouth to the forks on September 12, 1990.

Helicopter redd counts for steelhead were conducted on May 7 for the USR and May 8 for CR. In USR, the helicopter count was conducted from the Sawtooth Hatchery weir up to the mouth of Pole Creek and in Alturas Lake Creek from the mouth to the Pettit Lake road bridge. In CR, the helicopter steelhead redd count was conducted from the narrows to Orogrande. During May 13 to 15, we conducted ground steelhead redd counts on Pole Creek from the mouth to the diversion and on the Salmon River from Pole Creek to Chemeketan Campground. On April 23 and 24, we conducted ground counts on CR from the mouth to Orogrande.

The number of female chinook and steelhead spawning in the USR was estimated as the number of females released above the Sawtooth Hatchery weir multiplied by pre-spawning survival observed at Sawtooth Hatchery (0.95 for chinook; 0.98 for steelhead, Alsager 1990). Egg deposition was estimated as the number of female spawners multiplied by the average fecundity (4,500 eggs/female for chinook; 4,734 eggs/female for steelhead, Alsager 1990). In CR, the number of female chinook spawners was estimated assuming one redd per female as we observed in the USR. Chinook fecundity for CR (4,400 eggs) was based on estimates from the nearby Red River trapping facility (McGehee 1989).

The 1985 to 1987 female chinook escapement numbers are based on the ratio of the 1988 total redd count to trend count (43 total; 27 trend) and past trend counts. The 1988 and 1989 female chinook escapement estimates were based on the ground redd counts.

## Hatchery Supplementation

### Upper Salmon River

Supplementation evaluation efforts in the USR currently concentrate on chinook for brood year 1989 because of their critical status relative to A-run natural steelhead. The life stages outplanted in 1990 and their respective strata were: adult chinook into Frenchman Creek, upper Pole Creek, and Smiley Creek; adult steelhead into the Salmon River; adipose-clipped fingerling steelhead into Smiley Creek and the Salmon River; and chinook parr into the Salmon River. A major factor in the selection of the adult supplementation sites was the absence of natural reproduction as determined by our ground redd counts. The source of all chinook used for supplementation in the USR were returns to Sawtooth weir. Steelhead used for supplementation were obtained from fish returning to Sawtooth Hatchery weir and Pahsimeroi Hatchery weir.

Annual seeding levels for supplementation were selected based upon the availability of chinook adults and the levels needed for evaluation. We evaluated outplant success as survival to parr and smolt stage. We estimated total parr abundance for the outplant sites in July by stratified snorkel transects (three strata, six sections) extending from 1.0 km above to 2.0 km below outplant sites.

A total of 15 female and 15 male adult chinook were released into Frenchman Creek at study section 2-A during August 18 to 24, 1990. The release site was located within a grazing exclosure that was also sampled for sediment monitoring (Torquemada and Platts 1988). No cattle were in the exclosure while the chinook were spawning. In the Pole Creek study area, a total of 14 female and 16 male adult chinook were released at study section 3-B during August 18 to 24, 1990. The Pole Creek release site was located within a meadow subjected to heavy sheep grazing. No sheep were in the meadow while the adults were spawning. In the Smiley Creek study area, 11 female and 15 male adult chinook were released at study site 2-A (4.5 km above the mouth). Picket weirs prevented the fish from moving above or below the release sites. Spawning activity was monitored on alternate days. Carcasses were cut open to confirm sex and determine completeness of spawning, and fork length was measured.

In 1990, a total of 528 adult steelhead trout were released into the USR. Of these fish, 358 (114 female and 244 male) were collected in the Sawtooth Hatchery trap, and 170 fish (105 female and 65 male) were collected at Pahsimeroi Hatchery and transported to the USR for release. Seventy of the adult steelhead from Pahsimeroi Hatchery were outplanted on April 20 just below Hell Roaring Creek, and the remaining 100 fish were outplanted at the mouth of Hell Roaring Creek on April 9. Adult steelhead from Sawtooth Hatchery were released at the Sawtooth weir.

Adipose-clipped steelhead fingerlings were released into the Salmon River and Smiley Creek to supplement natural production. The total number of adipose-clipped steelhead released into the Salmon River in 1990 was 304,907. These fish were released in three groups. The first outplant was at Hell Roaring Creek bridge on October 5, and 97,515 fish were released. The second outplant was made in the Salmon River 2 km above Sawtooth Hatchery on October 10, and 119,819 fish were released. The third release was at the Hell Roaring Creek bridge on October 17, and 87,573 fish were released. On Smiley Creek, 6,150 adipose-clipped steelhead were released into stratum 2, 5 km above the mouth.

On August 16, 1990, 2,000 chinook parr were released into the Salmon River at the Hell Roaring Creek bridge. These parr were reared at Sawtooth Hatchery.

**Crooked River**

In CR, 65 female and 92 male adult chinook salmon were released at the Crooked River bridge (16 km above the mouth). Fish were obtained from Dworshak National Fish Hatchery and Kamiah Fish Hatchery. Spawning progress was monitored with the same methods used in the USR.

A total of 251 (162 female and 89 male) adult steelhead were outplanted into CR at the Crooked River bridge on May 18, 1990. These fish were collected at Dworshak National Fish Hatchery and trucked to CR for release.

On April 25, 1990, 214,633 adipose-clipped steelhead smolts were released into CR at the Crooked River bridge to supplement natural production. These fish were obtained from the Kamiah Hatchery.

On March 28, 1990, 300,400 spring chinook smolts were released into CR at the Crooked River bridge to supplement natural chinook production. On October 17, 1990, 339,100 chinook parr were released at the Crooked River bridge. All chinook outplanted into CR were obtained from Kamiah Hatchery.

## Parr Abundance

Parr abundance by species and age class was estimated by snorkeling through established sections (Petrosky and Holubetz 1985). Surveys were conducted in 31 sections on CR during July 6 to 9, 1990 and in 81 sections on the USR during July 19 to 24, 1990. Total abundance of steelhead and chinook parr were estimated by stratified sampling (Schaeffer et al. 1979).

## PIT Tagging

Chinook and steelhead parr were PIT-tagged (Passive Integrated Transponder) in their summer rearing areas during August 16 to 22, 1990 for the USR and August 2 to 8, 1990 on CR. Additional pre-smolts and smolts were collected and PIT-tagged during the fall and spring emigration trapping operations (see Emigration Trapping section).

We collected fish for PIT-tagging with a Smith-Root model 12 electrofisher or seine, depending on which method was most suitable for each particular site and species. Seines were used primarily to sample pools and the electrofisher was used to sample riffles.

The electrofisher was operated with a 30.5-cm diameter anode ring on a 2.0-m pole, 2.4-m rattail cathode, voltage setting between 200 and 400 V, and pulse rates of 90 cycles/s when fishing primarily for chinook and 30 cycles/s for steelhead. Conductivity in the USR drainage ranges from 37 to 218 umhos/cm (Emmett 1975). The conductivity on CR ranges from 35 to 50 umhos/cm (Mann and Von Lindern 1987). We observed that nylon netting tied completely around the anode ring reduced the incidence of electrical burn marks and fish mortality. This modification did not impair capture effectiveness.

Tagging procedures included anesthetizing fish with MS-222 and injecting PIT tags into the body cavity using a 12-gauge hypodermic needle and modified syringe. The needle was oriented anteriorly to posteriorly and inserted just off the mid-ventral line, about 1/4 of the distance between the tip of the pectoral fin and the pelvic girdle. Immediately after the needle entered the body cavity, it was rotated to change the angle so the bevel of the needle made contact with the inner surface of the body wall. The tag was then inserted.

After tagging, tag presence was confirmed using a hand-held detection and decoding device. The National Marine Fisheries Service (NMFS) has found that once a functional tag has been successfully implanted in a fish, the tag failure rate has been less than 1% (Prentice et al. 1986). Fork length was measured to the nearest 1.0 mm on all fish that were PIT-tagged and all fish that were too small to tag. Fish weight was measured to the nearest 0.1 g on most of the fish tagged using a Port-O-Gram balance. We summarized length data by location for both species, and for chinook, we also grouped length data by parr origin (natural spawning, adult outplants). Perforated 1.0 x 0.5 m plastic tote boxes were used to hold fish before tagging, during recovery, and for 24-hour delayed mortality tests.

A hand-held PIT tag detector was used to detect and send the tag codes to a battery powered laptop computer. The laptop computer used a program supplied by NMFS to organize tag codes and associated data into tag files. Copies and printouts of these tag files were made daily.

We conducted tests on chinook and steelhead in both study areas to determine delayed mortality and tag loss. All fish tagged were held for 24 hours in perforated plastic tote boxes in the stream sections they were tagged in before release.

## Emigration Trapping

We monitored fall and spring emigration of juvenile anadromous fish in the USR with a floating scoop trap equipped with a 1.0-m wide inclined traveling screen (Midwest Fabrications Inc., Corvallis, Oregon). The trap was attached below the permanent weir at Sawtooth Hatchery. Water was funneled to the trap from a 3.1-m wide bay of the weir with a temporary picket weir covered with 6 mm hardware cloth. To evaluate the spring 1990 (chinook brood year 1988) emigration, the trap was operated from March 9 to May 16, 1990. The trap was operated from August 24 to November 7, 1990 to evaluate fall emigration (brood year 1989).

On CR, a smaller version of the Sawtooth weir trap was used to evaluate the 1990 emigrations. The trap had a 1.0-m wide inclined traveling screen and was located 0.2 km above the mouth of CR. A rock weir was installed to funnel fish to the trap. The trap operated from March 3 to May 24, 1990 to evaluate the spring emigration. High water and mechanical problems caused the trap to be out of operation on May 11 and May 13. For the fall 1990 emigration, the trap was operated from August 30 to November 16, 1990.

The overall run estimates obtained from emigration trapping operations are totals of the daily run estimates and are based on trap efficiencies calculated for different ranges of flows and daily trap catches. We used the length frequency of the steelhead catch to estimate age composition of the steelhead runs.

## Survival Rates

A major objective of this project is to estimate smolt production from naturally-spawning adults and determine factors that affect their survival.

We used PIT tag detections at the Lower Snake and Columbia River dams as the basis for smolt production estimates. In this method, we use our parr population estimates from snorkel counts and then PIT tag representative groups of parr. We then compare the detections of these PIT tag groups at the LGR Dam with the detections that Buettner and Nelson (1990) observe for fish PIT-tagged at their traps at the head of LGR pool. If we assume that their tagged fish are detected at the dams at the same rate as our tagged fish, and that both groups suffer the same tagging mortality and migration mortality through LGR, then we can estimate the number of USR and CR smolts surviving to the head of LGR pool. To make this estimate we used the following equation:

$$^{PTD}USR\ /\ ^{PTD}LGR\ pool = {}^{S}LGR\ pool$$

Where:

$PTD_{USR}$ = Proportion of the USR PIT-tagged parr and emigrants detected at LGR Dam.

$^{PTD}LGR$ pool = Proportion of LGR pool PIT-tagged smolts detected at LGR Dam.

$^{S}LGR$ pool = The proportion of the USR PIT-tagged fish surviving to head of LGR pool.

Then we multiply this estimate of the proportion of PIT-tagged parr and emigrants surviving to the head of LGR pool by the population estimate to get the estimate of smolts surviving to the head of LGR pool.

When our estimate of smolt production indicated that there may be an error in the PIT tag method, we used a monthly survival estimate for a comparison. In this method, we have to make the assumptions that all monthly survival rates (S) are equal, that our snorkel counts accurately estimate the parr populations, and that our trap accurately estimates the number of fish leaving the study area during the fall and spring emigration periods. We then can use the following equations to estimate smolt production at the study area.

$$PP_{July} \times S^2 - E_f = PP_{winter}$$

Where:

$PP_{July}$ = July parr population estimate

S = Monthly survival

$E_f$ = Fall emigration

$PP_{winter}$ = Overwintering populations

$$PP_{winter} \times S^6 = E_S$$

Where:

$PP_{winter}$ = Overwintering population

S = Monthly survival

$E_S$ = Spring emigration

Since we have estimates of the July parr population, the fall emigration, and the spring emigration, we can then solve for S. We then multiplied the July parr population estimate by $S^8$ to estimate the number of smolts produced at the study area. To compare this estimate to the PIT tag detection estimate we multiplied it by our estimate of migration survival to LGR pool from PIT tag detections to get an estimate of survival to LGR pool.

## Creel Survey

We collected creel survey data on CR to evaluate angler harvest and determine angler impact on anadromous parr populations. Creel survey data were collected from May 26 to September 29, 1990 from the mouth of CR to the forks. Creel survey data were collected using methodologies defined by Nielsen and Johnson (1983). Analysis was done using the IDFG Fisheries Survey Manual (McArthur 1990). No creel survey information was collected on the USR.

# RESULTS

## Upper Salmon River

### Physical Habitat

Physical habitat data for 1990 have been entered into the IDFG physical habitat data base. The management of this data base is being handled by Idaho Habitat Evaluation for Off-Site Mitigation Record personnel and is reported in Scully et al. (1991).

## Adult Escapement and Redd Counts

In 1990, 615 (167 females) of the 1,488 adult chinook captured at the Sawtooth Fish Hatchery adult trap were released above the weir to spawn naturally (Table 1). Rotenone from the fish eradication treatment of Yellowbelly Lake escaped past the detoxification station, and 65 adult chinook were observed killed. Additional adults may have been killed but not observed by the crew sent in to assess the extent of the fish kill (Idaho Department of Fish and Game 1990).

A total of 107 chinook redds were observed during ground counts compared to the helicopter count of 60 (Table 1). However, 30 of the redds counted from the ground were in our supplementation sections, which are not counted from the air.

In 1990, 358 adult steelhead (114 females) returning to Sawtooth Hatchery weir were released above the weir to spawn naturally (Alsager 1990). An additional 170 adult steelhead (105 females) from Pahsimeroi Hatchery were released into USR between Hell Roaring Creek bridge and Alturas Lake Creek on April 19 and 20, 1990 (Table 2). On May 8, 1990, 56 steelhead redds were observed from a helicopter during counts on USR from the Sawtooth Hatchery weir to the uppermost Highway 75 bridge. We observed an additional four steelhead redds during ground counts of other possible spawning areas on May 13 to 15, 1990.

## Hatchery Supplementation

In 1990, a total of 40 adult female chinook, 2,000 chinook parr, 105 adult female steelhead, and 311,057 adipose-clipped steelhead parr were outplanted into the USR (Alsager 1990). Supplementation data for the brood years 1985 to 1990 are summarized in Tables 3 and 4.

The adult steelhead were outplanted for general supplementation. The adult chinook were outplanted by project personnel as part of our supplementation evaluation and were counted as part of the 33% of the adult chinook run released above the Sawtooth Hatchery weir to spawn naturally. The chinook parr were outplanted in partial mitigation for the 4,202 age 0 chinook killed in the rotenone accident.

Estimated abundance of chinook parr produced from the 9 female adult chinook outplanted in 1989 was 2,304 $\pm$ 1,833 (alpha = 0.05). The 2,000 chinook parr were outplanted after we had conducted our snorkel counts and were not included in parr abundance calculations. In the future, we will only outplant adult chinook and steelhead in order to estimate egg-to-parr survival at different adult escapement levels. In addition, our adult supplementation data will be incorporated into the Chinook Supplementation Evaluation Research Project currently being developed.

Table 1. Adult escapement, redd counts, and estimate of eggs deposited (in thousands) for upper Salmon River, brood year 1985 to 1990.

| | Chinook Salmon Brood Year | | | | | |
|---|---|---|---|---|---|---|
| | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 |
| Total escapement | 625 | 876 | 506 | 552 | 470[b] | 615 |
| Female escapement | 180 | 248 | 252 | 275 | 73[b] | 167[c] |
| Helicopter redd count | 83 | 105 | 124 | 76 | 52 | 60 |
| Ground redd count | - | - | - | 261 | 123 | 107 |
| Eggs per female[a] | 4,530 | 5,156 | 5,399 | 5,653 | 5,456 | 4,501 |
| Estimated eggs deposited | 815.4 | 1,278.7 | 1,360.5 | 1,554.5 | 671.1 | 481.6 |

[a] Number is average eggs/female observed at Sawtooth Fish Hatchery.
[b] Portions of the Sawtooth Fish Hatchery weir was pulled from June 12-16 due to high water and uncounted fish probably passed the weir.
[c] Chinook escapement above Sawtooth Hatchery was reduced by at least 65 fish due to a rotenone kill.

Total escapement, female escapement, and eggs/female data are from Sawtooth Hatchery brood year reports. Redd count data are from Idaho Department of Fish and Game redd count reports.

Table 2. Adult steelhead trout escapement, redd counts, and estimate of eggs deposited (in thousands) for upper Salmon River, brood year 1985 to 1990.

| | Brood Year | | | | | |
|---|---|---|---|---|---|---|
| | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 |
| Total escapement | 206 | 1,956 | 979 | 635 | 378 | 528[a] |
| Female escapement | 92 | 322 | 383 | 136 | 157 | 219[a] |
| Eggs per female[a] | 5,640 | 4,468 | 4,854 | 5,069 | 5,637 | 4,734 |
| Estimated eggs deposited | 518.8 | 1,438.7 | 1,859.0 | 689.3 | 885.0 | 1,036.7 |

[a] 1990 totals include 170 adult steelhead (105 females) from Pahsimeroi Hatchery released into the Salmon River.

Total escapement, female escapement, and eggs/female data are from Sawtooth Hatchery brood year reports. Redd count data are from Idaho Department of Fish and Game redd count reports. Pre-spawning mortality included.

Table 3. Upper Salmon River chinook supplementation, summary by brood year 1985 to 1989.

| | Brood Year | | | | | |
|---|---|---|---|---|---|---|
| | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 |
| Adult females | 19 | 0 | 6 | 30 | 9 | 40 |
| Eyed Eggs | 0 | 0 | 28,000 | 56,530 | 0 | 0 |
| Fry | 0 | 0 | 48,000 | 326,000 | 0 | 0 |
| Fall parr | 0 | 0 | 43,000 | 0 | 2,000 | 0 |
| Smolts | 0 | 0 | 0 | 0 | 0 | 0 |

Table 4. Upper Salmon River steelhead supplementation in thousands, summary by brood year 1985 to 1989.

| | Brood Year | | | | | |
|---|---|---|---|---|---|---|
| | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 |
| Adult Females | 0 | 10.5 | 0 | .83 | 0 | 1.1 |
| Fry | 1,276.5 | 832.4 | 678.6 | 537.7 | 361.0 | 0 |
| Fall parr | 0 | 0 | 0 | 0 | 0 | 311.1 |
| Smolts | 0 | 0 | 0 | 0 | - | - |

## Parr Abundance

Estimates for total parr abundance from snorkel counts in the USR during summer 1990 were: 14,267 ± 7,485 (alpha = 0.05) age 0 chinook; 4,065 ± 841 age 1+ steelhead; and 1,310 ± 527 age 2+ steelhead. Densities of age 0 chinook were the lowest observed since we began collecting data, except in the Salmon River headwaters and in our supplementation evaluation strata (Table 5). Densities of both age 1+ and 2+ steelhead were among the lowest observed by this project (Table 6 and 7).

## PIT Tagging

We PIT-tagged 1,082 chinook parr and 826 steelhead parr in USR during August. These numbers were well below those tagged in 1989 (5,388 chinook and 1,351 steelhead), primarily because of the low chinook parr densities in 1990. Overall combined collecting, tagging, and 24-hour delayed mortalities were 1.0% for chinook and 0.5% for steelhead parr.

Data for the mean lengths for parr collected in the USR are summarized in Table 8. In general, the chinook parr resulting from adult outplants were smaller than chinook parr from natural spawners. (Discussed in Supplementation section, page 50.)

## Spring 1990 Emigration Trapping

During spring 1990, we estimated the total emigration for chinook and steelhead to be 23,918 ± 10,085 and 5,314 ± 2,876, respectively (alpha = 0.10). We captured 1,942 chinook smolts with an overall trapping efficiency of 8.1%, and 181 steelhead juveniles with an overall trapping efficiency of 3.4%. During the later portion of the spring 1990 emigration period, we also captured 504 emigrating sockeye/kokanee O. Nerka. If we assume that these fish were captured by our trap with the same trap efficiency as chinook smolts during this period (6.1%), then we can estimate a run of 8,302. In spring 1990, chinook and steelhead smolts had the same peak period of emigration with fair numbers of chinook emigrating before this peak period and fair numbers of steelhead emigrating after this peak period. The sockeye/kokanee did not emigrate until the very end of the trapping season (Figure 3).

Estimated age composition of steelhead emigrants was 27.6% (1,417) age 1, 37.0% (1,966) age 2, and 35.4% (1,881) age 3 and older. (Note: Juvenile steelhead have a birthday in the spring, so age 2+ parr become age 3 smolts, etc.) Based on the summer 1989 parr abundance estimates (Kiefer and Forster 1990), we estimated that 15.4% of the chinook summer parr, 40.2% of age 1+ steelhead summer parr, and 57.7% of age 2+ and older steelhead summer parr emigrated in spring 1990.

Table 5. Density (number/100 $m^2$) of age 0 chinook in the upper Salmon River during July, 1987 to 1990.

| Stratum | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|
| Salmon River | | | | |
| 3,4 | 7.0 | 13.8 | 9.7 | 0.4 |
| 5,6 | 0.3 | 4.1 | 3.6 | 0.1 |
| 7 | 20.3 | 13.3 | 32.9 | 3.2 |
| 8 | 10.3 | 3.9 | 0.6 | 0 |
| 9 | 7.4 | 1.4 | 2.6 | 7.1 |
| 10 | 0.1 | 0 | 32.0 | 9.8 |
| Salmon River side channels | | | | |
| 3,4 | - | 16.0 | 24.6 | 1.0 |
| 5,6 | - | 17.9 | 0.6 | 1.2 |
| 7 | - | 16.1 | 85.7 | 4.7 |
| 8,9,10 | - | 6.8 | 1.7 | 0 |
| Pole Creek | | | | |
| 1 | 25.7 | 2.0 | 0.9 | 0 |
| 2 | 2.9 | 4.3 | 11.2 | 0.3 |
| 3 | 0 | 0.1 | 55.8 | 12.6 |
| 4 | 0 | 0 | 0.3 | 0 |
| 5 | - | - | 0 | 0 |
| Alturas Lake Creek | | | | |
| 1 | 18.3 | 8.6 | 20.3 | 1.9 |
| 2 | 0.6 | 0.9 | 2.5 | 0.4 |
| 3 | 0.1 | 0 | 7.7 | 0.1 |
| Smiley Creek | | | | |
| 1 | 35.2 | 6.9 | 14.1 | 0.3 |
| 2 | 1.1 | 13.5 | 23.4 | 0 |
| Beaver Creek | | | | |
| 1 | - | 2.1 | 0.4 | 0 |
| 2 | - | 0.4 | 20.8 | 0.1 |
| Frenchman Creek | | | | |
| 1 | 0 | 0.6 | 4.0 | 0.4 |
| 2 | 0 | 41.4 | 109.5 | 10.2 |

Table 6. Density (number/100 $m^2$) of age 1+ steelhead parr in the upper Salmon River during July, 1987 to 1990.

| Stratum | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|
| Salmon River | | | | |
| 3,4 | 0.1 | 0.2 | <0.1 | <0.1 |
| 5,6 | <0.1 | 0.1 | 0 | 0 |
| 7 | 0.7 | 0.4 | 0.2 | 0.3 |
| 8 | 0.4 | 0.4 | 0 | 0 |
| 9 | 8.5 | 2.8 | 2.6 | 4.5 |
| 10 | 7.3 | 3.5 | 8.4 | 4.5 |
| Salmon River side channels | | | | |
| 3,4 | - | 0.6 | 0.2 | 0.2 |
| 5,6 | - | 0 | 0 | 0 |
| 7 | - | 0 | 0 | 0 |
| 8,9,10 | - | 0.3 | 0 | 0 |
| Pole Creek | | | | |
| 1 | 3.0 | 2.1 | 0.1 | 0.2 |
| 2 | 5.1 | 0 | 0.5 | 0.3 |
| 3 | 0 | 0 | 0.3 | 0.2 |
| 4 | 1.3 | 4.8 | 0.8 | 0 |
| 5 | 0 | 0 | 0 | 0 |
| Alturas Lake Creek | | | | |
| 1 | 0.8 | 0.6 | 0.1 | <0.1 |
| 2 | 0.9 | 0.4 | 0 | <0.1 |
| 3 | 0 | 0.1 | 0.1 | 0.1 |
| Smiley Creek | | | | |
| 1 | 0.2 | 0 | 0.5 | 0.5 |
| 2 | 0 | 0.2 | 0.1 | 0 |
| Beaver Creek | | | | |
| 1 | - | 0.5 | 0.1 | 0.6 |
| 2 | - | 0.2 | 0 | 2.0 |
| Frenchman Creek | | | | |
| 1 | 1.8 | 0 | 1.5 | 2.6 |
| 2 | 0 | 0.1 | 0 | 0 |

Table 7. Density (number/100 $m^2$) of age 2+ steelhead parr in the upper Salmon River during July, 1987 to 1990.

| Stratum | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|
| Salmon River | | | | |
| 3,4 | <0.1 | <0.1 | 0.1 | <0.1 |
| 5,6 | <0.1 | <0.1 | 0 | 0 |
| 7 | 0 | 0.1 | 0.2 | 0.1 |
| 8 | 0.2 | 0.1 | 0.7 | 0 |
| 9 | 2.1 | 0.8 | 0.9 | 0.4 |
| 10 | 2.4 | 2.9 | 4.4 | 0.5 |
| Salmon River side channels | | | | |
| 3,4 | - | 0 | 0.2 | 0 |
| 5,6 | - | 0 | 0 | 0 |
| 7 | - | 0 | 0.4 | 1.2 |
| 8,9,10 | - | 0 | 0 | 0 |
| Pole Creek | | | | |
| 1 | 1.2 | 0.6 | 0.1 | 0 |
| 2 | 1.6 | 0 | 0.3 | 0 |
| 3 | 0.1 | 0 | 1.2 | 0.1 |
| 4 | 1.3 | 0.5 | 0.9 | 0.2 |
| 5 | 0.1 | 0.7 | 0 | 0 |
| Alturas Lake Creek | | | | |
| 1 | <0.1 | <0.1 | 0.1 | <0.1 |
| 2 | 0.5 | 0.3 | 0.1 | 0 |
| 3 | 0 | 0.1 | 0.1 | 0.1 |
| Siley Creek | | | | |
| 1 | 0.6 | 0 | 0.6 | 0.3 |
| 2 | <0.1 | <0.1 | <0.1 | 0.1 |
| Beaver Creek | | | | |
| 1 | - | 0 | 0.1 | 0.4 |
| 2 | - | <0.1 | 0 | 0.3 |
| Frenchman Creek | | | | |
| 1 | 2.2 | 0.61 | 2.3 | 1.0 |
| 2 | 0 | 0.11 | 0.1 | 0 |

Table 8. Mean lengths (mm) of PIT-tagged parr from upper Salmon River, August 1990.

| Tag site | Chinook outplant method | Number chinook measured | Chinook average length | Number steelhead measured | Steelhead average length |
|---|---|---|---|---|---|
| SR-10 | Natural | 99 | 81 | 281 | 130 |
| SR-3B | Natural | 55 | 79 | 63 | 68 |
| SR-7SA | Natural | 25 | 87 | 2 | 64 |
| SR-9 | Natural | 70 | 79 | 274 | 132 |
| SR-AC1C | Natural | 407 | 76 | 30 | 125 |
| SR-SC1B | Natural | 3 | 87 | 41 | 136 |
| SR-FC1B | Natural | 7 | 92 | 25 | 133 |
| SR-HC | Natural | 5 | 75 | 23 | 105 |
| SR-PC1B | Natural | 13 | 89 | 84 | 133 |
| SR-PC3B | Adult | 516 | 53 | 0 | - |
| SR-FC3A | Adult | 347 | 56 | 1 | 132 |
| Total | Adult | 863 | 54 | - | - |
| Total | Natural | 684 | 78 | 824 | 126 |
| Grand Total | | 1,547 | 65 | 824 | 126 |

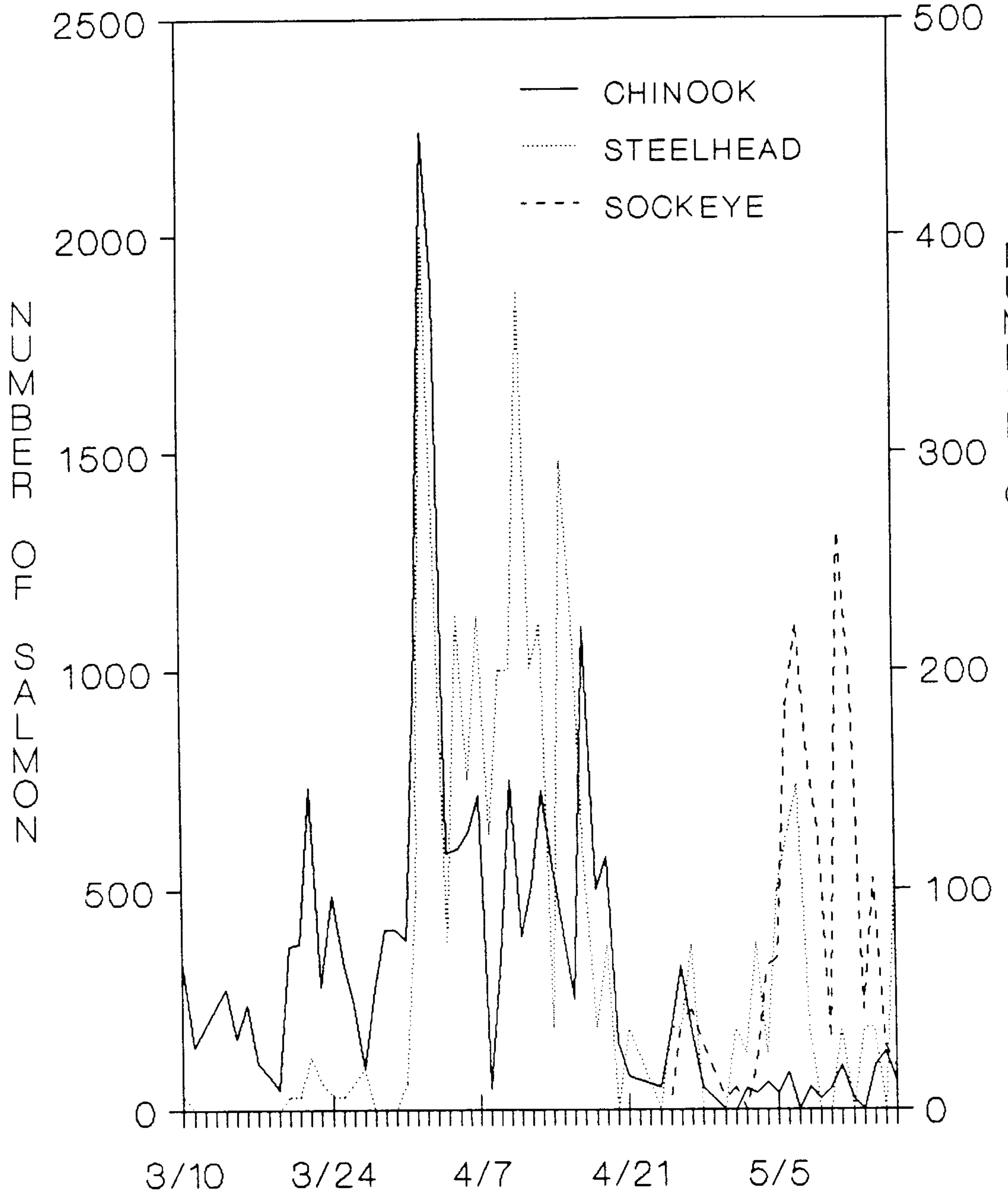


Figure 3. Spring 1990 upper Salmon River chinook, steelhead, and sockeye emigration timing.

**Fall 1990 Emigration Trapping**

During fall 1990, we estimated the total emigration for chinook and steelhead to be 9,490 ± 1,757 and 2,710 ± 1,973, respectively (alpha = 0.10). We captured 1,738 chinook parr with an overall trapping efficiency of 18.3% and 413 steelhead with an overall trapping efficiency of 15.2%. Estimated age composition of steelhead emigrants were 36% (976) age 0, 21% (569) age 1+, and 43% (1,165) age 2+. The estimated percentages of summer parr populations that emigrated in the fall were 66.5% for chinook, 14.0% for age 1+ steelhead, and 88.8% age 2+ steelhead. In fall 1990, both chinook and steelhead parr appeared to emigrate during the entire period we sampled (Figure 4).

During fall 1990, the Sawtooth weir trap also captured a large number of adipose fin-clipped hatchery steelhead. These hatchery steelhead were predominately from the outplant of 304,907 age 1 parr released into the USR on October 5, 10, and 17, 1990. We captured a total of 23,244 of these hatchery steelhead with an estimated trapping efficiency of 18.9% and a total run estimate of 122,984.

**Dam Detections**

Mean travel time was calculated during the spring 1990 emigration from PIT-tagged chinook and steelhead smolts captured at Sawtooth weir trap and later detected at LGR Dam 748 km downstream. Two distinct patterns for chinook travel time were observed (Figure 5). Travel time decreased from approximately 52 days from the first day of trapping to about 37 days on April 22, and then quickly dropped to approximately 23 days until the end of trapping. With the low numbers of smolt-sized steelhead captured in spring 1990, we did not have enough data to develop a travel time curve for steelhead. An estimate of travel time was made from the 13 steelhead detections at LGR Dam, and travel time was estimated to be 33.8 + 8 days (alpha = 0.10).

The combined PIT tag detection rates at the Lower Snake and Columbia River smolt collecting dams for the spring 1990 USR smolts were 21.7% for chinook, 17.4% for sockeye, 0% for age 1 and age 2 steelhead, and 25.0% for age 3 and older steelhead (steelhead spring birthday). For the fall 1989 USR emigrants, the detection rates were 3.2% for chinook, 0% for age 1+ steelhead, and 9.8% for age 2+ and older steelhead. Detection data for the August 1989 PIT-tagged parr were summed by strata (Table 9). Overall, the smolt collecting dams collected 4.1% of the PIT-tagged chinook, 2.1% for the age 1+ steelhead and 6.2% of the age 2+ and older steelhead parr from the August 1989 tagging. The younger steelhead will rear another year or two before emigrating. The combined PIT tag detection rates for the smolts tagged at the Snake River trap by Buettner and Nelson (1990) were 64.4% for chinook and 79.0% for steelhead.

Our PIT tag detection data indicates that LGR Dam is not very efficient at collecting sockeye smolts. In spring 1990, the first dam encountered by smolts (LGR Dam) detected 7.4% of the sockeye/kokanee smolts we PIT-tagged from

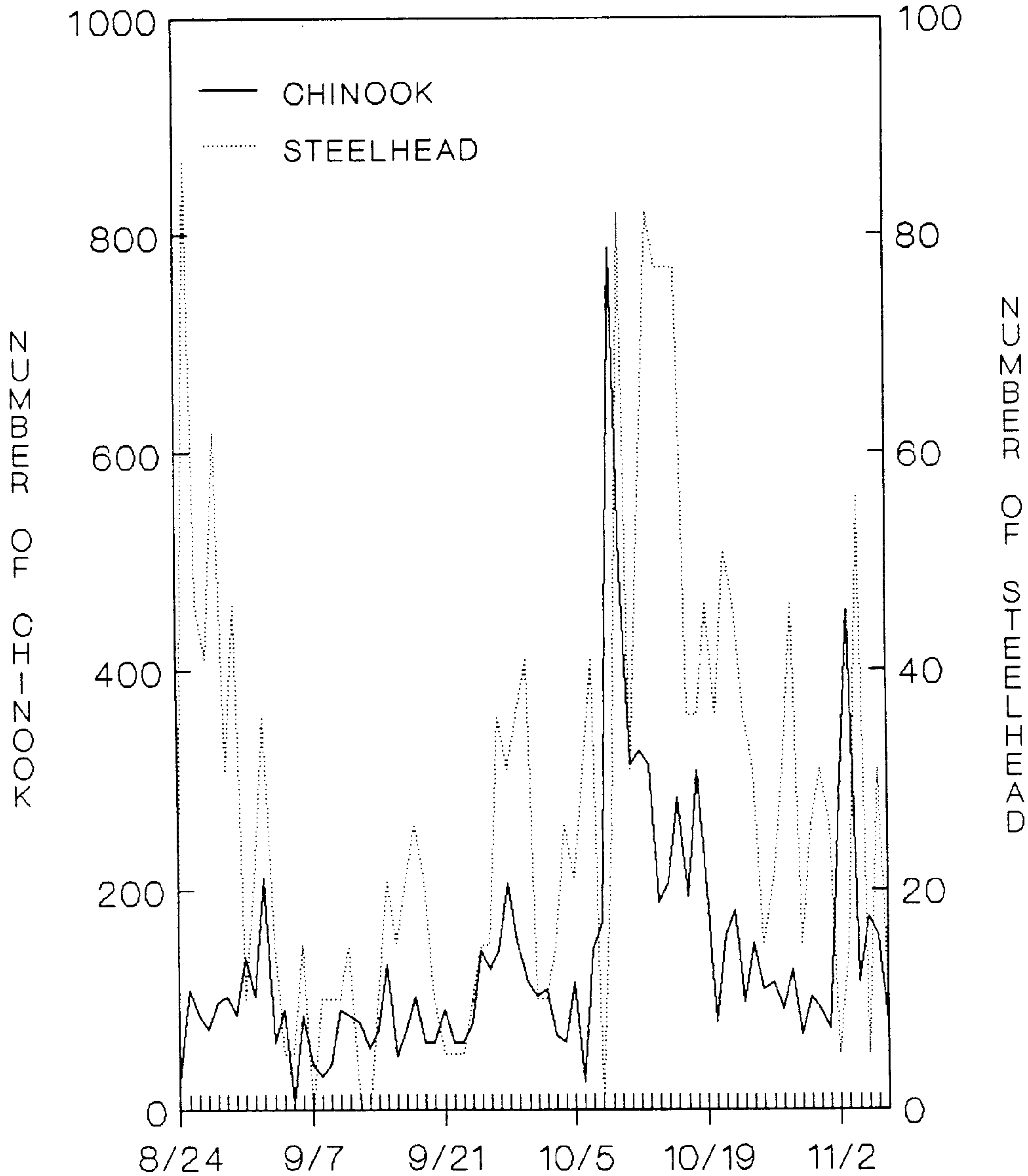


Figure 4. Fall 1990 upper Salmon River chinook and steelhead emigration timing.

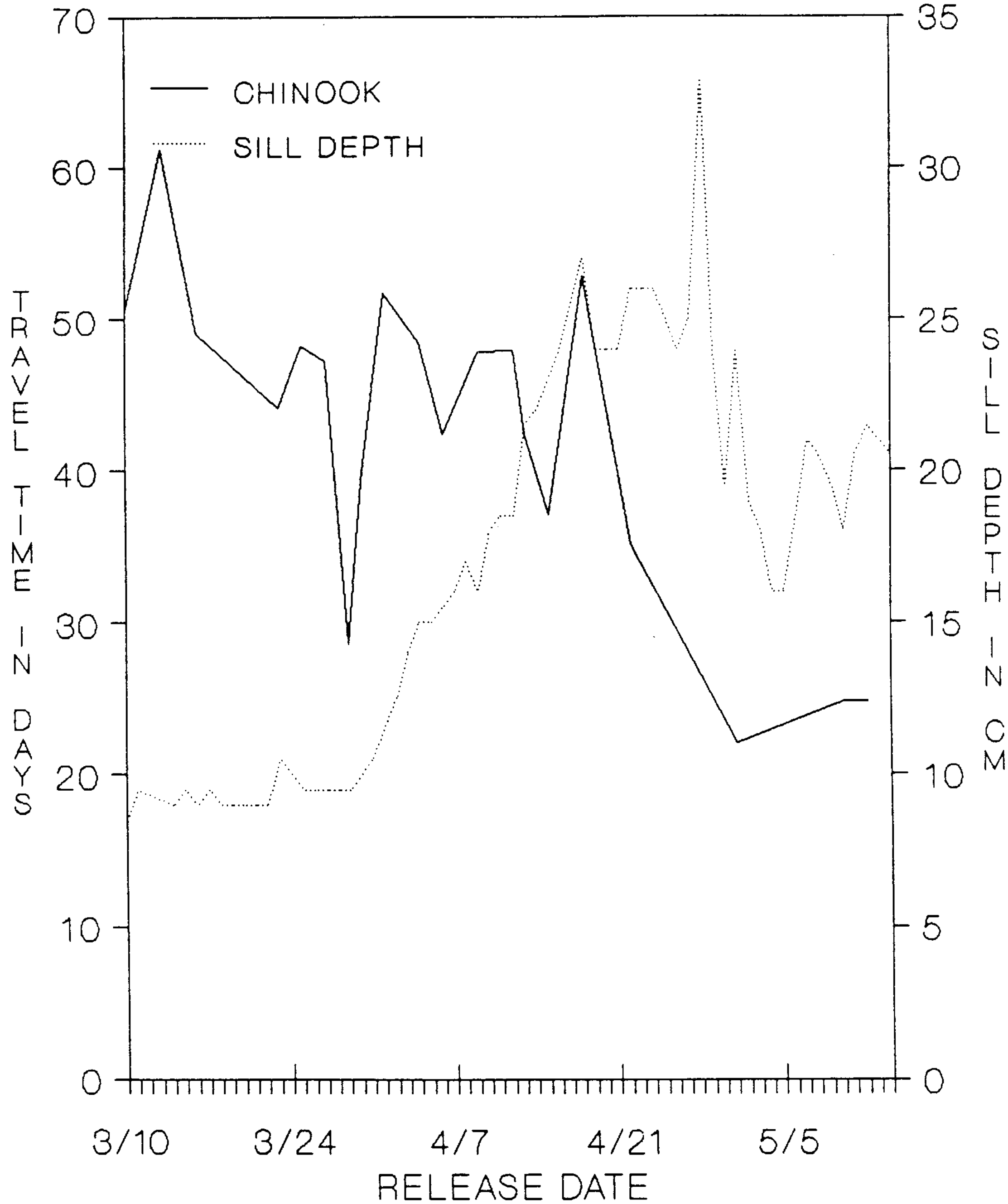


Figure 5. Spring 1990 chinook smolt travel time and sill depth from Sawtooth weir trap to Lower Granite Dam.

Table 9. Detections at the lower Snake and Columbia River smolt collecting dams of August PIT-tagged parr from upper Salmon River, 1990.

| | Chinook | | | Steelhead age 2+ | | |
|---|---|---|---|---|---|---|
| Stratum | Number tagged | Number detected | Percent detected | Number tagged | Number detected | Percent detected |
| SR-3 | 604 | 17 | 2.8 | 39 | 2 | 5.1 |
| SR-7 | 545 | 29 | 5.3 | 8 | 1 | 12.5 |
| SR-9 | 781 | 43 | 5.5 | 92 | 5 | 5.4 |
| SR-10 | 213 | 24 | 11.3 | 80 | 8 | 10.0 |
| HC-1 | 199 | 14 | 7.0 | 12 | 1 | 8.3 |
| FC-1 | 81 | 8 | 9.9 | 16 | 0 | 0 |
| FC-2 | 420 | 23 | 5.5 | 0 | - | - |
| SC-1 | 235 | 14 | 6.0 | 11 | 2 | 18.2 |
| SC-2 | 536 | 10 | 1.9 | 0 | - | - |
| ALC-1 | 1,036 | 5 | 0.5 | 0 | - | - |
| ALC-3 | 144 | 5 | 3.5 | 0 | - | - |
| BC-2 | 276 | 14 | 5.1 | 0 | - | - |
| PC-1 | 148 | 7 | 4.7 | 55 | 1 | 1.8 |
| PC-2 | 161 | 9 | 5.6 | 8 | 0 | 0 |
| TOTALS | 5,379 | 222 | 4.1 | 321 | 20 | 6.2 |

the USR. The next dam encountered (Little Goose Dam) detected 7.6%. Since the smolts collected at LGR Dam are transported, for Little Goose Dam to collect virtually identical numbers of USR sockeye/kokanee smolts indicates that Little Goose Dam is more efficient at collecting sockeye smolts.

To evaluate the relationship of smolt size to migration survival, we calculated smolt size and detection percentages (Table 10). In spring 1990, only those chinook smolts from USR having a fork length of 100 mm or larger had a significantly different (higher) PIT tag detection rate (alpha = 0.05) than the other length groups analyzed. Only those steelhead smolts greater than 129 mm (age 3 and older) (steelhead spring birthday) were detected at the smolt collecting dams; presumably the smaller (younger) steelhead will rear another year or two before emigrating.

We were concerned that predation on natural chinook smolts by the hatchery steelhead smolts released into the Salmon River just below the Sawtooth Hatchery weir may be causing significant mortality. We compared PIT tag detection rates of USR natural chinook emigrating before and after the steelhead smolt releases for the past three years and found no significant difference (alpha = 0.05). Apparently, the hatchery steelhead smolts are not preying upon the natural chinook smolts to any significant degree.

**Survival Rates**

Brood years 1987 through 1989 egg-to-parr survival rates in the headwaters of the USR for adult outplants and natural spawners averaged 18.8% (Table 11). Estimated egg-to-parr survival rates in the entire USR for naturally-spawning chinook for five of the past six years averaged 4.8% (Table 12).

Two different methods were used to estimate parr-to-smolt survival in 1989 to 1990. The first used PIT tags and comparative detections at Lower Snake and Columbia River dams from our study and Snake River trap information (Buettner and Nelson 1990) to estimate survival to the head of LGR pool. The second method used parr abundance and emigration trapping data to estimate monthly survival and parr-to-smolt survival at the study area.

Using the PIT tag method for August 1989 parr, the estimated parr-to-smolt survival to the head of LGR pool was 6.4% for chinook and 7.8% for age 2+ and older steelhead.

Parr-to-smolt survival estimates based on monthly survival rates were 28.0% for age 0 chinook and 90.2% for age 2+ and older steelhead. To compare the monthly survival estimate to the PIT tag estimates, we used the spring 1990 PIT tag estimates of USR smolts to LGR pool survival (33.7% for chinook and 31.6% for steelhead age 3 and older) (steelhead spring birthday) to estimate survival rate to smolt at LGR pool; for chinook 28.0% X .337 = 9.4%, and for steelhead age 2+ and older 90.2 X .316 = 28.5%.

Table 10. Smolt length and PIT tag detection at lower Snake and Columbia River smolt collecting dams for upper Salmon River, spring 1990.

| Length (mm) | Chinook Number tagged | Chinook Number detected | Chinook Percent detected |
|---|---|---|---|
| < 80 | 126 | 27 | 21.4 |
| 80 - 89 | 479 | 93 | 19.4 |
| 90 - 99 | 375 | 87 | 23.2 |
| > 99 | 83 | 28 | 33.7 |
| Total | 1,063 | 235 | 22.1 |

| Length (mm) | Steelhead Number tagged | Steelhead Number detected | Steelhead Percent detected |
|---|---|---|---|
| < 90 | 75 | 0 | 0 |
| 90 - 129 | 38 | 0 | 0 |
| > 129 | 62 | 16 | 25.8 |
| Total | 175 | 16 | 9.1 |

Table 11. Estimated egg-to-parr survival rates (%) from the headwaters of the upper Salmon River adult outplants and natural spawners, brood years 1987 to 1989.

| Adult origin | Population parameter | Brood Years 1987 | 1988 | 1989 |
|---|---|---|---|---|
| Adult outplants | Females Outplanted | 5 | 30 | 9 |
| | Egg Deposition | 26,995 | 169,590 | 50,400 |
| | Parr Production | 8,625 | 27,438 | 2,295 |
| | Egg-to-Parr survival | 32.0 | 16.1 | 4.6 |
| Natural spawners | Redds Observed | 0 | 6 | 4 |
| | Egg Deposition | - | 33,918 | 22,400 |
| | Parr Production | - | 8,500 | 2,759 |
| | Egg-to-Parr Survival | - | 25.1 | 12.3 |

Table 12. Egg-to-parr survival rates for natural chinook in upper Salmon River, brood years 1984 to 1989.

| | Brood Year | | | | |
|---|---|---|---|---|---|
| | 1984 | 1986 | 1987 | 1988 | 1989 |
| Estimated egg deposition in thousands[a] | 1,095.1 | 1,287.7 | 1,360.5 | 1,724.2 | 688.8 |
| Parr production in thousands | 73.5 | 65.7 | 70.3 | 88.0 | 14.2 |
| Egg-to-parr survival | 6.7% | 5.1% | 5.2% | 5.1% | 2.1% |

[a] From Table 2.

In addition, we used detection rates for PIT-tagged emigrants and Buettner and Nelson's (1990) detection rates to estimate fall and spring emigrant-to-smolt survival at the head of LGR pool. For fall 1989 emigrants, we estimate that 5.0% of the age 0 chinook emigrants and 12.4% of the age 2+ and older steelhead emigrants survived to LGR pool. For spring 1990 emigrants, the USR to LGR pool survival rates were 33.7% and 31.6% for age 0 chinook and age 3 and older steelhead (steelhead spring birthday), respectively.

We PIT-tagged 391 of the sockeye/kokanee we captured in spring 1990. Of these fish, 68 were detected at the smolt collecting dams for a detection rate of 17.4%. From this detection rate and the detection rate of Snake River chinook smolts tagged by Buettner (1990) (64.4%), we estimate that 27% of the sockeye/ kokanee survived to the head of LGR pool.

### Smolt Production

From our survival rate estimates we are able to estimate smolt production from the USR to the head of LGR pool three different ways. The first uses the survival rate estimates based on August 1989 PIT tagging for smolt production estimates of 9,959 chinook and 383 steelhead. The second combines the fall 1989 and spring 1990 emigration and survival rate estimates for smolt production estimates of 11,124 chinook and 774 steelhead. The third method uses the monthly survival estimate adjusted for survival to the head of LGR pool for smolt production estimates of 14,683 chinook and 928 steelhead.

## Crooked River

### Physical Habitat

Physical habitat data for 1990 have been entered into the IDFG physical habitat data base. The management and initial analysis of this data base is being handled by Idaho Habitat Evaluation for Off-Site Mitigation Record personnel and is reported in Scully et al. (1991).

### Adult Escapement and Redd Counts

Accurate adult escapement numbers for chinook were available for the first time from CR with the completion of the weir and trap in summer 1990. In 1990, the total adult chinook escapement to CR was 27, with 9 of those being female. The run extended from June 29 to September 23, 1990 (McGehee 1990). Two-thirds of the run were transported to the Red River holding ponds, but were returned and released on August 31 into CR just below the narrows (5 km from the mouth). Chinook female escapement and total egg deposition estimates for 1985-1990 are provided in Table 13.

Table 13. Estimated chinook salmon adult escapement, redd counts, and number of eggs deposited for Crooked River, 1985 to 1990.

| | Chinook Salmon Brood Year | | | | | |
|---|---|---|---|---|---|---|
| | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 |
| Female escapement[a] | 16 | 14 | 27 | 43 | 15 | 95 |
| Trend redd Count | 10 | 9 | 17 | 27 | 3 | [b] |
| Ground redd Count | - | - | - | 43 | 15 | 10[c] |
| Eggs per female[d] | - | - | 4,010 | - | 4,400 | 4,200 |
| Estimated eggs deposited | 67,536 | 59,094 | 108,270 | 181,503 | 66,000 | 399,000 |

[a] Female escapement was estimated for 1985 - 1987 based on 1/1 ratio of female escapement to ground redd counts observed in USR, and 43/27 ratio of ground to trend redd counts observed in 1988. Female escapement in 1988 and 1989 was assumed to equal the ground redd count. Pre-spawning mortality included.

[b] See Discussion section of this report.

[c] Redd counts were conducted before 157 adult chinook (86 females) were outplanted into Crooked River from Dworshak National Fish Hatchery.

[d] Average number of eggs/female obtained from nearby Red River trapping facility in 1985 and 1987. We used 1985 and 1987 average from brood years for which data were not available.

On September 12, 1990, we counted 10 redds for the total probable spawning area in CR and 0 redds for the traditional trend count reach (narrows to the forks). The helicopter redd count of the traditional trend count reach on CR was not conducted because we did not observe redds in the trend count area during our ground count.

On April 15, 1990, a total of 258 adult steelhead (167 females) were outplanted from the bridge on CR. Since the adult trap was not operable, we do not know the natural escapement but believe it to be less than 25% of the total escapement.

On May 8, 1990, we conducted a helicopter steelhead redd count on CR from the narrows to the Orogrande townsite. We counted a total of 219 redds during this aerial count. On April 23 and 24, we conducted ground redd counts for steelhead and observed 144 redds from the narrows to Orogrande and 36 redds in the remainder of CR. The data for steelhead in CR are not complete enough to estimate escapement or egg deposition.

**Hatchery Supplementation**

Although not part of our research investigations, hatchery supplementation of chinook and steelhead in CR has occurred regularly during the project period (Tables 14 and 15). Beginning in 1990, only adult chinook and steelhead will be outplanted in CR so that we can evaluate egg-to-parr survival rates at different seeding levels. In addition, our data will be incorporated into the Chinook Supplementation Evaluation Research Project.

In 1990, 258 adult steelhead (167 females) and 157 adult chinook (92 females) were outplanted into CR from Dworshak National Fish Hatchery. Six female chinook pre-spawning mortalities (2 transport mortalities) were observed out of a total of 35 female carcasses examined. Successful female spawners had a mean egg retention of 16 ± 9 (alpha = 0.10) eggs.

**Parr Abundance**

Chinook parr densities in 1990 were the lowest observed since data began being collected in 1984 (Table 16). We estimated the CR age 0 chinook parr abundance in 1990 to be 3,678 ± 1,928 (alpha = 0.05).

Steelhead age 1+ parr densities in 1990 were the lowest or among the lowest observed since intensive snorkeling began in 1986, while age 2+ steelhead densities were in the mid-range of values observed since 1986 (Table 17). We estimated the CR steelhead parr abundance in 1990 to be 2,344 ± 644 age 1+ and 1,843 ± 611 age 2+ (alpha = 0.05).

In summer 1990, the Elk City Ranger District of the Nez Perce National Forest contracted with Clearwater Bio-Studies of Sherwood, Oregon to conduct a

Table 14. Crooked River chinook supplementation in thousands, summary by brood year, 1985 to 1990.

| | Brood Year | | | | | |
|---|---|---|---|---|---|---|
| | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 |
| Adult Females | 0 | 0 | 0 | 0 | 0 | .92 |
| Fry | 349.7 | 0 | 200.1 | 401.5 | 0 | - |
| Fall parr | 251.3 | 227.5 | 0 | 0 | 339.1 | - |
| Smolts | 0 | 0 | 199.7 | 300.4 | - | - |

Table 15. Crooked River steelhead supplementation, summary by brood year, 1985 to 1990.

| | Brood Year | | | | | |
|---|---|---|---|---|---|---|
| | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 |
| Adult females | 1,522 | 0 | 468 | 0 | 0 | 167 |
| Fry | 0 | 87,750 | 0 | 0 | 0 | 0 |
| Fall parr | 0 | 0 | 0 | 0 | 0 | - |
| Smolts | 140,825 | 158,538 | 201,325 | 88,000 | 214,633 | - |

Table 16. Density (number/100 $m^2$) of age 0 chinook in Crooked River, August 1986 to 1990.

| Stratum | 1986 | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|---|
| Headwaters | - | - | <0.1 | 0.1 | 0 |
| I | 14.0 | 3.0 | 23.8 | 28.4 | <0.1 |
| II | 1.1 | 16.5 | 19.7 | 19.7 | <0.1 |
| Canyon | - | - | 8.0 | 10.3 | 1.0 |
| III | 57.8 | 22.3 | 36.6 | 58.7 | 5.0 |
| IV | 71.8 | 15.4 | 42.2 | 59.0 | 4.7 |
| Relief Creek | - | - | 0.8 | 45.5 | 0 |
| Ponds A[a] | 62.9 | 3.2 | 65.4 | 206.1 | 0.6 |
| Ponds B | - | - | - | 268.0 | 8.1 |

[a] In 1986 - 1988 the data for connected ponds was combined and is reported here as Ponds A.

Table 17. Density (number/100 $m^2$) of age 1+ and age 2+ steelhead parr for Crooked River, 1986 to 1990.

| Stratum | 1986 | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|---|
| | | | Age 1+ Steelhead | | |
| Headwaters | - | - | 1.5 | 0.2 | 0.4 |
| I | 6.8 | 4.3 | 5.2 | 1.9 | 0.2 |
| II | 11.7 | 10.8 | 8.8 | 4.4 | 1.5 |
| Canyon | - | - | 11.4 | 4.1 | 1.0 |
| III | 6.2 | 6.1 | 10.3 | 6.5 | 2.5 |
| IV | 7.2 | 7.2 | 7.5 | 3.4 | 1.5 |
| Relief Creek | - | - | 19.1 | 5.2 | 0.2 |
| Ponds A[a] | 4.8 | 42.4 | 17.8 | 7.2 | 1.2 |
| Ponds B | - | - | - | 10.1 | 0.1 |
| | | | Age 2+ Steelhead | | |
| Headwaters | - | - | 0.2 | 0.3 | 0.1 |
| I | 0.2 | 0.7 | 0.2 | 0.8 | 0.3 |
| II | 1.1 | 3.7 | 0.4 | 1.4 | 1.3 |
| Canyon | - | - | 1.2 | 2.1 | 1.2 |
| III | 0.2 | 2.8 | 0.5 | 1.8 | 1.4 |
| IV | 0.3 | 1.5 | 7.1 | 1.5 | 1.1 |
| Relief Creek | - | - | 0.6 | 1.8 | 0.1 |
| Ponds A[a] | 0.3 | 4.8 | 1.6 | 1.7 | 1.0 |
| Ponds B | - | - | - | 2.2 | 0.3 |

[a] In 1986-1988 the data for conected ponds was combined and is reported here as Ponds A.

post-rehabilitation project survey of CR. This survey included snorkel counts to estimate parr populations by the ratio estimation method described by Hankin (1984). Clearwater BioStudies conducted snorkel surveys on 30.1% of the habitat units that they identified for CR (Clearwater BioStudies Inc. 1990). They estimated the anadromous parr populations in CR to be 9,893 ± 1,742 age 0 chinook, 4,169 ± 663 age 1+ steelhead, and 1,828 ± 408 age 2+ steelhead.

**Creel Survey**

During 1990, project personnel conducted a creel survey on CR to estimate the proportion of the wild/natural steelhead parr population that is being harvested. From this creel survey, we estimate that 62% (2,018 ± 1,638; alpha = 0.05) of the age 2+ wild/natural steelhead population was harvested. In addition, we estimated that 74% (4,829 ± 2,643; alpha = 0.05) of the residualized hatchery steelhead smolts were harvested.

**PIT Tagging**

We PIT-tagged a total of 767 chinook and 562 steelhead parr in CR during August. These numbers were below those we tagged in 1989 (3,297 chinook and 925 steelhead), primarily because of low chinook densities in 1990. We held all tagged fish for 24-hour delayed mortality tests. Overall combined collecting, PIT tagging, and 24-hour delayed mortalities for chinook and steelhead were 3.7% and 0.9%, respectively. The average length of chinook parr was similar among strata, except for fish from stratum I which were smaller (Table 18).

**Spring 1990 Emigration Trapping**

During spring 1990, we estimated the total emigration for chinook and steelhead to be 10,517 ± 1,470 and 981 ± 309, respectively (alpha = 0.10). We captured 3,667 chinook smolts with an overall trapping efficiency of 32.0%, and 119 steelhead juveniles with an overall trapping efficiency of 12.1%. In spring 1990, both chinook and steelhead smolts from CR appeared to emigrate during the same period (Figure 6). The graph of the run timing indicates that a significant proportion of the smolt emigration may have occurred after we removed our trap on May 24.

Estimated age composition of steelhead emigrants were 34% (336) age 1, 15% (147) age 2, and 51% (500) age 3 and older (steelhead spring birthday). Based on the summer 1989 parr abundance (Kiefer and Forster 1990), we estimated that 9.7% of chinook parr, 1.5% of age 1+ steelhead, and 13.5% age 2+ and older steelhead emigrated in spring 1990.

Table 18. Average fork lengths (mm) of parr from PIT tagging strata on Crooked River, August 1990.

| Strata | Chinook | | Steelhead | |
|---|---|---|---|---|
| | Number Measured | Mean Length | Number Measured | Mean Length |
| I | 160 | 54 | 39 | 152 |
| II | 95 | 67 | 9 | 101 |
| Canyon | 141 | 70 | 136 | 135 |
| III | 218 | 67 | 81 | 121 |
| IV | 201 | 66 | 290 | 121 |
| Total | 815 | 65 | 555 | 126 |

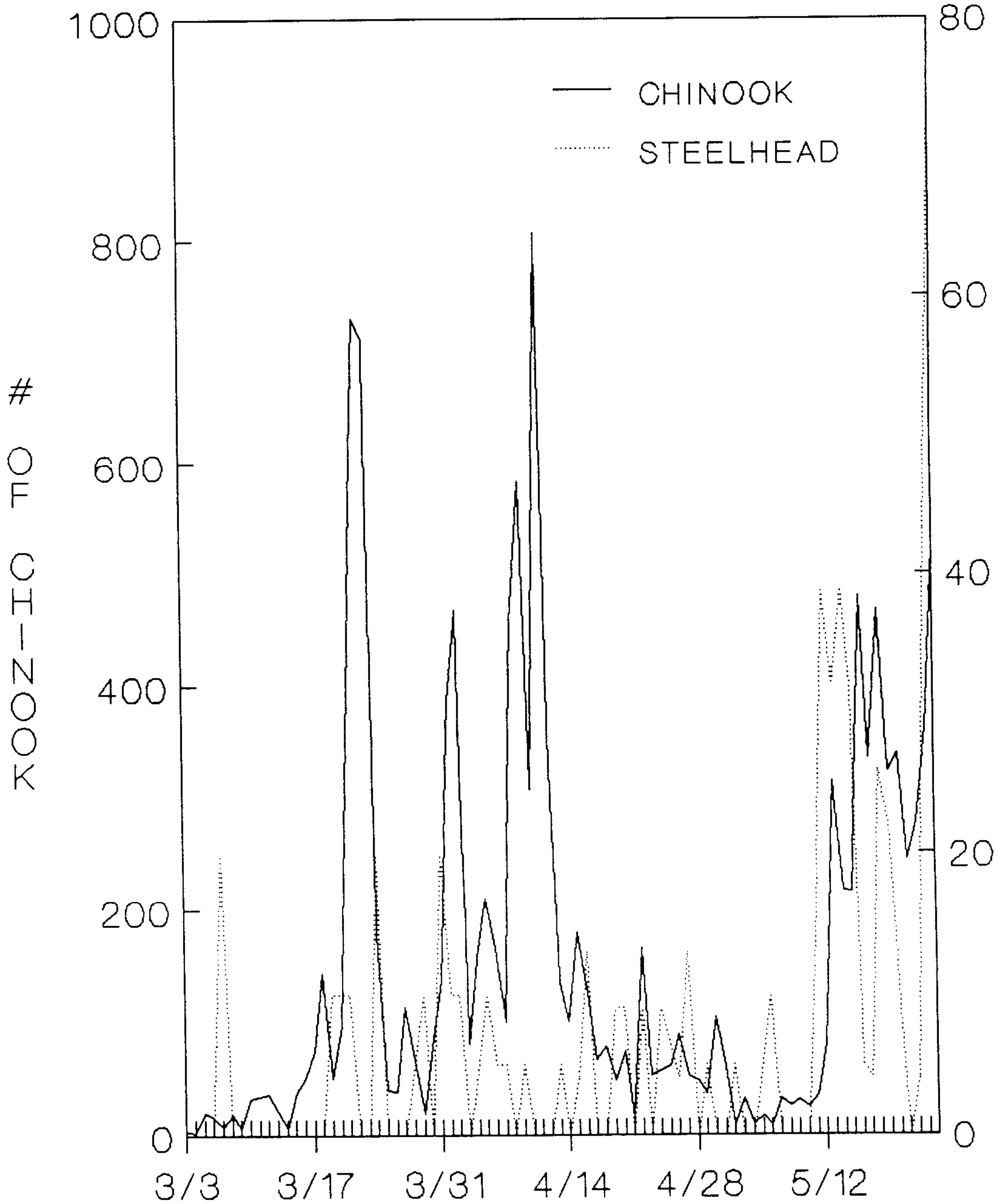


Figure 6. Spring 1990 Crooked River chinook and steelhead emigration timing.

## Fall 1990 Emigration Trapping

During fall 1990, we estimated the total emigration for chinook and steelhead to be 1,622 ± 216 and 1,008 ± 512, respectively (alpha = 0.10). We captured 681 chinook parr with an overall trapping efficiency of 42.0% and 215 steelhead with an overall trapping efficiency of 21.3%. In the fall 1990, the majority of both chinook and steelhead parr from CR emigrated during a relatively short time period in October (Figure 7). Estimated age composition of steelhead emigrants were 18% (181) age 0, 20% (202) age 1+ steelhead, and 63% (635) age 2+ and older. The estimated percentages of summer parr populations that emigrated in the fall were 16.4% for chinook, 7.7% for age 1+ steelhead, and 34.4% for age 2+ and older steelhead.

## Dam Detections

Mean travel time was calculated during the spring 1990 emigration from PIT-tagged chinook and steelhead smolts captured at Crooked River trap and later detected at LGR Dam, 266 km downstream. Although there was considerable fluctuation, we observed two different patterns for chinook travel time (Figure 8). First, we observed a progressive decrease in travel time from 79 days for March 6 to about 32 days for May 8. From May 8 until the end of trapping (March 24), the travel time fluctuated around 20 days. We had considerably fewer dam detections for CR steelhead than for chinook, but in general, steelhead travel time was less than chinook. Although there was some fluctuation, after a quick decrease from 59 to 18 days, steelhead travel time slowly decreased to about 13 days (Figure 8).

The combined PIT tag detection rates at the Lower Snake and Columbia River smolt collecting dams for the spring 1990 CR smolts were 25.9% for chinook, 0% for age 1 steelhead, 5.6% for age 2 steelhead, and 39.3% for age 3 and older steelhead (steelhead spring birthday). For the fall 1989 CR emigrants, the detection rates were 4.0% for chinook, 0% for age 1+ steelhead, and 17.9.% for age 2+ and older steelhead. Detection data for the August 1989 PIT-tagged parr were summed by strata (Table 19). Overall, the smolt collecting dams collected 3.1% of the PIT-tagged chinook, 3.4% of the age 1+ steelhead, and 9.9% of the age 2+ and older steelhead parr from the August 1989 tagging. The combined PIT tag detection rates for the smolts tagged at the Clearwater River trap by Buettner and Nelson (1990) were 54.6% for chinook and 70.4% for steelhead.

To evaluate the relationship of smolt size to migration survival, we calculated smolt size and detection percentages (Table 20). As in USR, only those chinook smolts from CR having a fork length of 100 mm or larger had a significantly different (higher) PIT tag detection rate (alpha = 0.05) than the other length groups analyzed. For steelhead, predominately only those larger than 129 mm (age 3 and older) (steelhead spring birthday) were detected at the smolt collecting dams; presumably the smaller (younger) steelhead will rear another year or two before migrating.

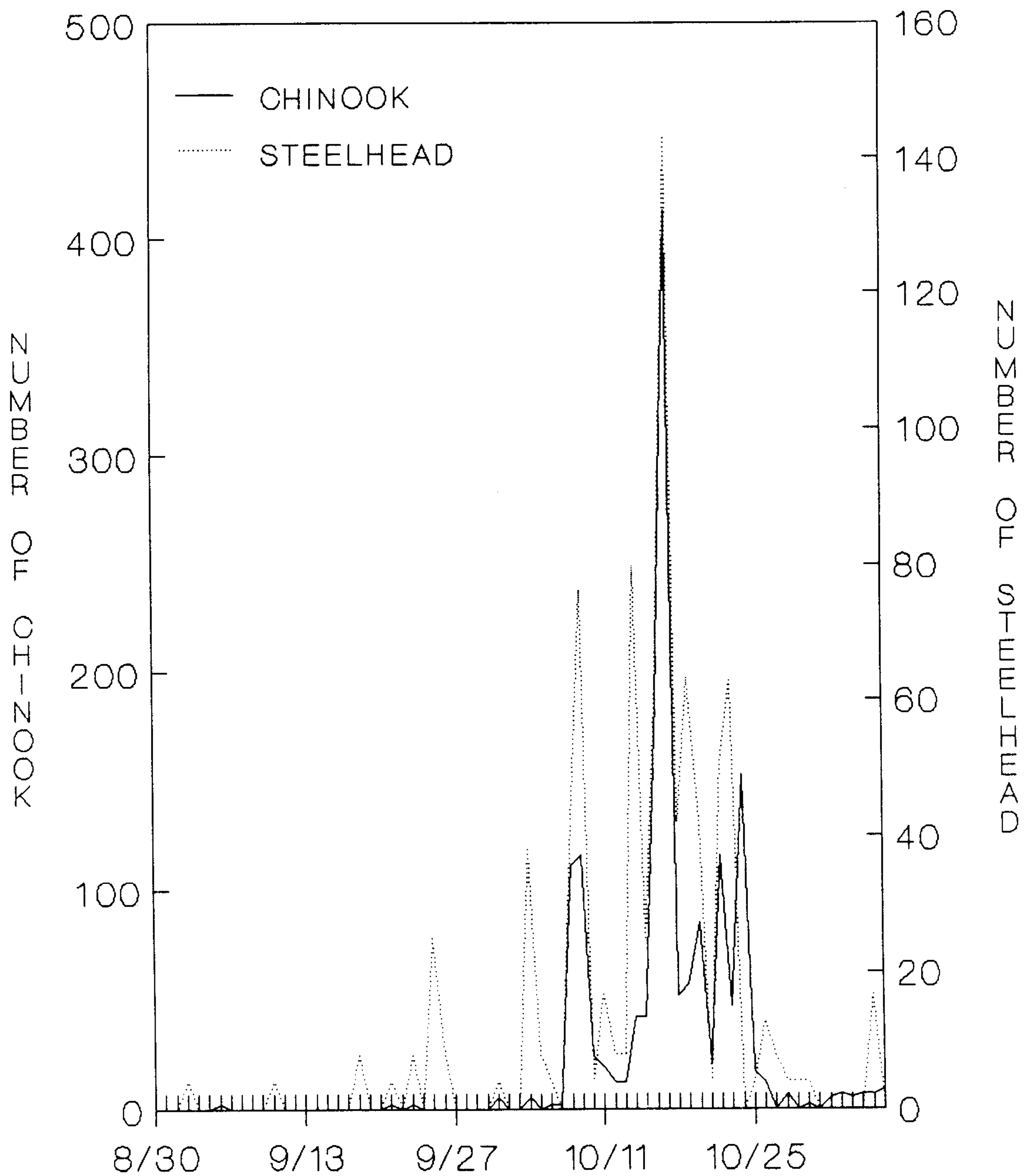


Figure 7. Fall 1990 Crooked River chinook and steelhead emigration timing.

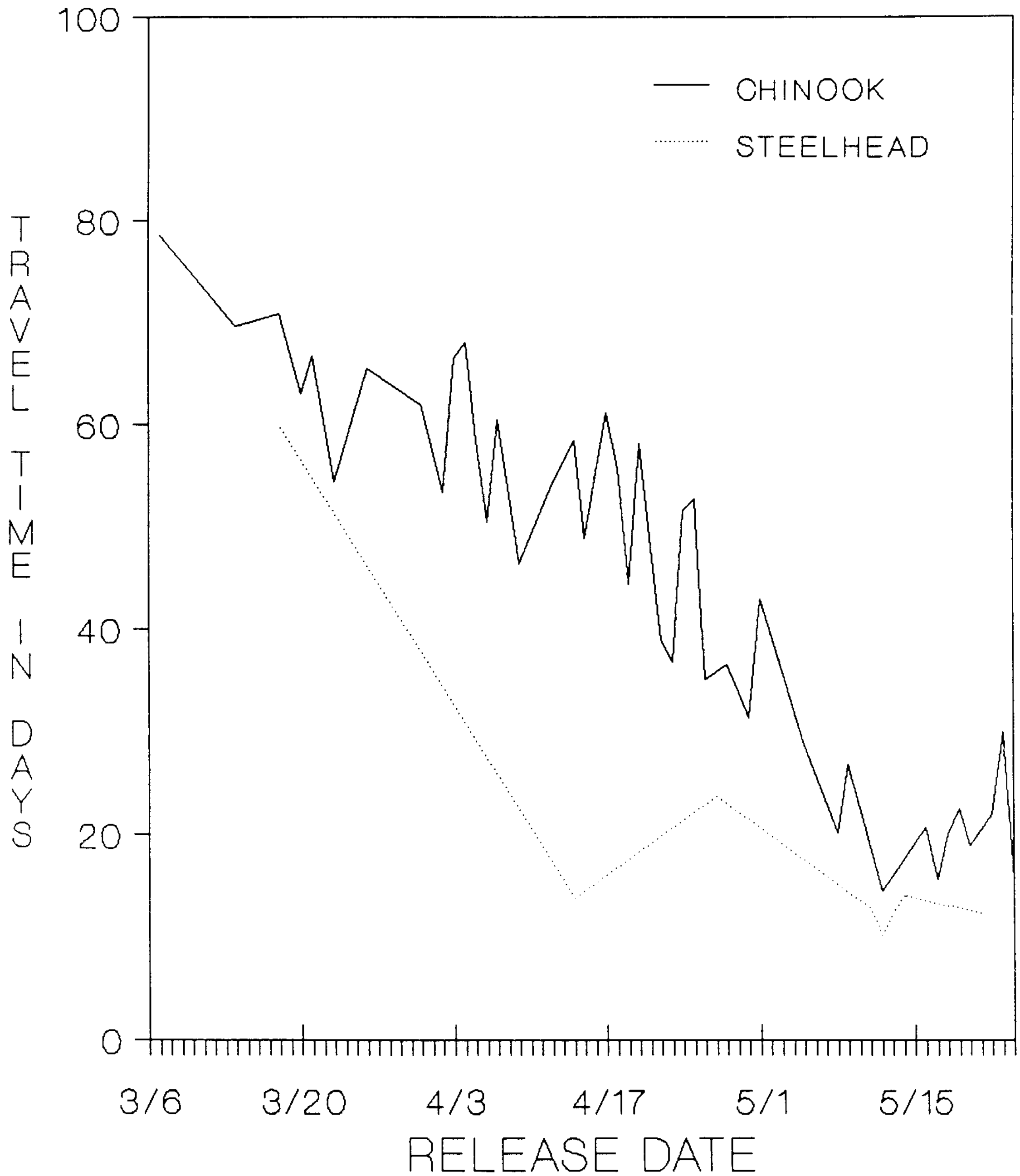


Figure 8. Spring 1990 chinook and steelhead smolt travel time from Crooked River trap to Lower Granite Dam.

Table 19. Detections at the lower Snake and Columbia River smolt collecting dams of August PIT-tagged parr from Crooked River, 1990.

| | Chinook | | | Steelhead age 2+ | | |
|---|---|---|---|---|---|---|
| Stratum | Number tagged | Number detected | Percent detected | Number tagged | Number detected | Percent detected |
| CR-I | 460 | 23 | 5.0 | 33 | 1 | 3.0 |
| CR-II | 530 | 18 | 3.4 | 21 | 2 | 9.5 |
| CR-Ill | 1,395 | 24 | 1.7 | 53 | 5 | 9.4 |
| CR-IV | 772 | 27 | 3.5 | 89 | 15 | 16.9 |
| CANYON | 282 | 16 | 5.7 | 56 | 2 | 3.6 |
| RELIEF C | 408 | 11 | 2.7 | 11 | 1 | 9.1 |
| TOTALS | 3,847 | 119 | 3.1 | 263 | 26 | 9.9 |

Table 20. Smolt length and PIT tag detection for Crooked River, spring 1990.

| Length (mm) | Chinook | | |
|---|---|---|---|
| | Number tagged | Number detected | Percent detected |
| < 70 | 24 | 7 | 25.9 |
| 70 - 79 | 349 | 82 | 23.5 |
| 80 - 89 | 709 | 180 | 25.4 |
| 90 - 99 | 367 | 101 | 27.5 |
| > 99 | 34 | 15 | 44.1 |
| Total | 1,483 | 385 | 26.0 |

| Length (mm) | Steelhead | | |
|---|---|---|---|
| | Number tagged | Number detected | Percent detected |
| < 90 | 45 | 0 | 0 |
| 90 - 129 | 13 | 1 | 7.7 |
| > 129 | 61 | 24 | 39.3 |
| Total | 119 | 25 | 21.0 |

## Survival Rates

Chinook egg-to-parr survival rates for CR were calculable for the first time with brood year 1989 parr. In 1989 we had an adult female chinook escapement estimate of 15 and an average of 4,400 eggs/female for an estimated egg deposition of 66,000. The best estimate of the 1990 CR chinook parr population is 9,893 (Clearwater BioStudies Inc. 1990) for an estimated chinook egg-to-parr survival rate of 15.0%. In 1991, we will be able to make our first estimate of the steelhead egg-to-parr survival in CR with the brood year 1990 parr.

Two different methods were used to estimate parr-to-smolt survival in 1989 to 1990. The first used PIT tags and comparative detections at Lower Snake and Columbia River dams from our study and Snake River trap information (Buettner and Nelson 1990) to estimate survival to the head of LGR pool. The second method used parr abundance and emigration trapping data to estimate monthly survival and parr-to-smolt survival at the study area.

Using the PIT tag method for August 1989 parr, the estimated parr-to-smolt survival to the head of LGR pool was 5.7% for age 0 chinook, 4.8% for age 1+ steelhead, and 14.1% for age 2+ and older steelhead. A majority of the age 1+ steelhead will rear another year before emigrating.

Parr-to-smolt survival estimates based on monthly survival rates were 12.1% and 10.7% for age 0 chinook and age 2+ and older steelhead, respectively. To compare the monthly survival estimates to the PIT tag estimates, we used spring 1990 PIT tag estimates of CR smolts to LGR pool survival (46.3% for chinook and 55.8% for steelhead) to estimate survival rate to smolt at LGR pool: for chinook 12.1% X .463 = 5.6%; 10.7% X .558 = 6.0% for steelhead age 2+ and older.

In addition, we used detection rates for PIT-tagged emigrants and Buettner and Nelson's (1990) detection rates to estimate fall and spring emigrant-to-smolt survival at the head of LGR pool. For fall 1989 emigrants, we estimate that 7.3% of the age 0 chinook emigrants and 25.4% of the age 2+ and older steelhead emigrants survived to LGR pool. For spring 1990 emigrants, the CR to LGR pool survival rates were 46.3% for age 0 chinook, 8.0% for age 2 steelhead, and 55.8% for age 3 and older steelhead (steelhead spring birthday).

## Smolt Production

From our survival rate estimates, we are able to estimate smolt production from CR to the head of LGR pool three different ways. The first uses the survival rate estimates based on August 1989 PIT tagging for smolt production estimates of 5,811 chinook, 466 for age 1+ steelhead, and 641 for age 2+ and older steelhead. The second combines the fall 1989 and spring 1990 emigration and survival rate estimates for smolt production estimates of 5,811 chinook and 314 steelhead. The third method uses the monthly survival estimate adjusted for survival to the head of LGR pool for smolt production estimates of 5,709 chinook and 273 steelhead.

# DISCUSSION

## Physical Habitat

Analysis for correlations between physical habitat, parr densities, and smolt production will be conducted in winter 1992.

## Adult Escapement and Redd Counts

The adult weirs at both study sites allow us to obtain accurate escapement numbers. These accurate escapement numbers are a critical part of our efforts to determine the relationship between adult escapement and smolt production.

The ground and helicopter redd counts also provide us with important information. Since we are working in study areas with known escapements, we are able to estimate the efficiency of each method in counting redds. Our data indicates that a total ground count just after the peak spawning time can accurately estimate chinook escapement with an assumed female to redd ratio of 1:1. This has allowed us to estimate total female chinook escapement in CR before the adult trap was built in 1990 and in the USR in 1989, when high water forced Sawtooth Hatchery personnel to remove weir panels for a week.

The redd counts also tell us where spawning has occurred. This information allows us to estimate egg-to-parr survival rates for natural chinook spawners in headwater tributary streams, and tells us where we should concentrate collection efforts for parr PIT tagging.

Chinook and steelhead escapements during the period of analysis (1984 to 1990) have been variable, but typically less than 25% of estimates of full seeding (Idaho Department of Fish and Game 1990) for both study areas.

Data indicates that the preferred chinook spawning areas in CR may be changing in response to some of the habitat rehabilitation work conducted there. Apparently, gravel cleaned during the habitat work in the lower meander section has encouraged the adult chinook to spawn in these areas and not in the upper meadow where they had traditionally spawned in the greatest numbers.

We hypothesize that there is a more natural component of the USR chinook population that spawns higher up in the drainage than the more hatchery-influenced component. The evidence for this hypothesis comes from the following three sets of data. First, during the period of our study (1987 to 1990), we have observed a bimodal distribution in the areas selected by adults for spawning. One concentration of spawning occurs just above the Sawtooth Hatchery weir and the other centers around the confluence of Alturas Lake Creek and the Salmon River. Second, we have estimated a much higher egg-to-parr survival rate from those chinook adults spawning higher up in the drainage. Third, in 1989, Robin Waples of the NMFS conducted electrophoretic analysis on chinook parr collected from the Salmon River, just upstream of Alturas Lake Creek and from Sawtooth Hatchery, and found significant differences at five different gene loci (Robin Waples, National Marine Fisheries Service, personal communication). However, the greater egg-to-parr survival rates in the headwaters could be a result of better habitat, and the genetic study could have been biased if the natural parr analyzed came from just a few adults. Data from our adult outplant evaluations indicates that habitat is the primary reason the headwater spawning chinook have a greater egg-to-parr survival. However, the natural spawners in the headwaters typically have a slightly greater egg-to-parr survival than the adult outplants, and even though this difference is slight, the consistency suggests a possible genetic difference. We know that in 1988 there were approximately 34 chinook redds in the Salmon River just upstream from Alturas Lake Creek where we collected the parr for Robin Waples' analysis, so bias resulting from parr coming from only a few adults probably did not occur.

## <u>Hatchery Supplementation</u>

Adult outplants of chinook in the USR headwater streams resulted in similar egg-to-parr survival as naturally-spawned fish when corrected for seeding levels (Figure 9). Based on this information, we believe we will be able to use adult outplants to help develop adult escapement to parr production curves at seeding levels above what can be observed for natural populations during current low natural escapement levels. Supplementation with other life stages will be discontinued in both study areas, except where incorporated into the supplementation research project currently being developed.

The significantly (alpha = 0.05) smaller size of chinook parr produced from adult outplants in upper Frenchman Creek (x = 56 mm) and upper Pole Creek (x = 53 mm) as compared to naturally-produced headwater USR parr (x = 81 mm) probably resulted from the late spawning and/or colder water. The adults used for this supplementation were taken from the very end of the run (late July) to ensure they would spawn soon after outplanting, whereas natural spawners in the USR headwaters in the past several years must be early-returning fish to get above the Busterback diversion before the diversion completely dewaters the stream (typically late June). The limited temperature data we have collected on the headwater streams (mid-day temperatures taken during snorkel counts and PIT tagging operations) indicate that the headwaters of the Salmon River (above Frenchman Creek) is warmer (x = 12.4°C) than either upper Frenchman Creek (x = 10.6°C) or upper Pole Creek (x = 9.1°C).

Overall, chinook parr densities during the study period 1987 to 1990 appear to be closely related to adult escapements and supplementation levels. In 1990, chinook parr abundance in both study areas were the lowest observed since we began collecting data in 1984. This can be directly attributed to the low natural escapements in 1989, low levels of supplementation, and the low egg-to-parr survival observed in the USR. We do not know what caused this low egg-to-parr survival. One possibility is that low water levels caused by several consecutive drought years may have resulted in heavy scour ice which crushed the eggs in the gravel.

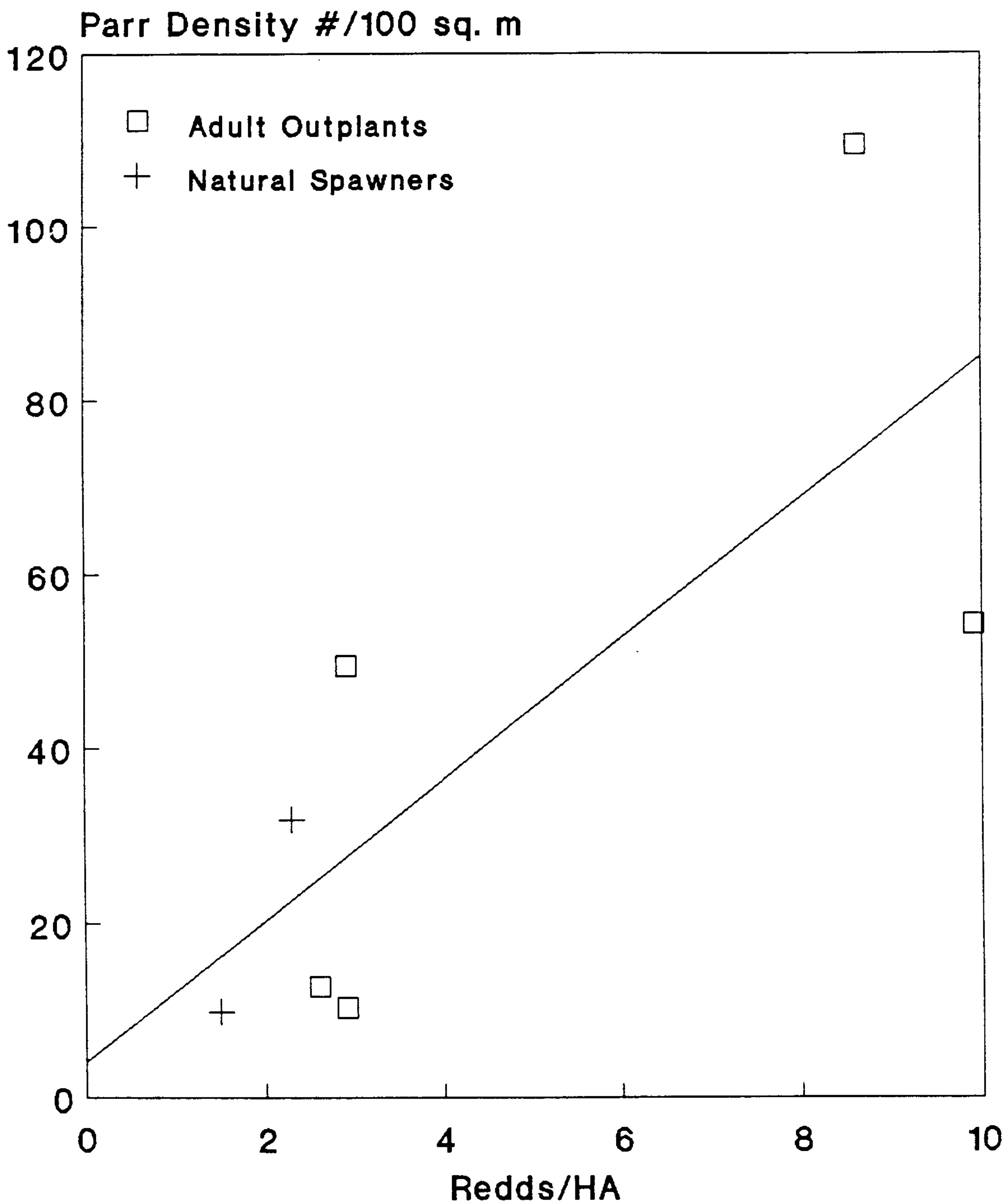


Figure 9. Number of chinook redds per hectare and resulting parr densities, upper Salmon River headwaters, 1990.

Steelhead parr populations dropped in both study areas with the elimination or reduction in supplementation. However, the drop was not major, indicating that survival of fry outplants were possibly low. We will be able to make our first estimate for egg-to-parr survival for steelhead after the 1991 field season because of the elimination of fry outplants.

## Creel Survey

Our data indicates that exploitation of wild/natural steelhead may be high in natural production areas. During 1990, project personnel conducted a creel survey on CR to estimate the proportion of the wild/natural steelhead parr population that is being harvested. To estimate the number of age 2+ steelhead present at the beginning of the fishing season, we added our snorkel count estimate to the estimated harvest of wild/natural steelhead during the first interval of the creel survey (Appendix 1) and assumed that natural mortality was minimal during this period. From this creel survey, we estimate that 62% (2,018 ± 1,638; alpha = 0.05) of the age 2+ wild/natural steelhead and 74% (4,829 ± 2,643; alpha = 0.05) of the residualized hatchery steelhead smolt populations were harvested. The estimates of harvest are believed to be inflated due to the only weekend days sampled in May and June being the season opener and free fishing day. These two days in all probability had a higher level of effort and harvest than a typical weekend day during this interval and could cause an overestimate of harvest and effort. Other researchers have estimated that angler harvest can remove a large portion of steelhead age 2+ parr populations (23-87%) (Pollard and Bjornn 1973, Thurow 1987, and Hillman and Chapman 1989).

If regulations were implemented in CR that would protect age 2+ wild/ natural steelhead, we would expect around a 40% increase in steelhead smolt production. This estimate of potential benefit is based on the assumptions that the actual exploitation is half of our estimate of 62% and that current population levels are so low that density-dependent mortality is not a factor.

Extreme caution is urged in using the harvest point estimates. Precision is very low with the 95% confidence interval being 10-fold in range; i.e. harvest for wild/natural steelhead of 12% to 112%. We show estimates to illustrate that this is an area that should be addressed. A more intense creel census with better estimates of emigration from tributaries to CR would allow for more precision in estimates.

## PIT Tagging

The numbers of chinook and steelhead parr PIT-tagged from both study areas in 1990 were below what we estimate is necessary to obtain enough detections at the dams for good statistical comparisons. The primary reasons for the low numbers were that chinook densities were too low to make collecting efficient and, because we spent more time collecting chinook, less time was available for collecting steelhead. Also, the steelhead populations were slightly lower.

Our data suggest there may be a bias in comparing PIT-tagged parr in streams to those tagged in hatcheries due to either higher mortality or tag loss of stream fish. PIT tag data used for calculating survival rates should be viewed with possible limitation.

In all years we PIT-tagged in both study areas (1988 to 1990), the naturally-produced chinook parr from the USR were significantly larger (alpha = 0.1) than those from CR. This is contrary to what elevation and thermal units for growth would predict. Possible explanations are the higher conductivity (more productivity) in USR and genetic differences in stocks.

For the first time in CR, PIT-tagged chinook parr from a stratum (stratum I) were significantly different (smaller) from the other strata. This is most likely a result of our collecting many of the stratum I parr from the hatchery pond headboxes where they had been trapped with little incoming food.

Short-term (24-hour) mortalities for PIT tagging operations were well within our goal of less than 5%, and were similar to other PIT tagging studies (Prentice et al. 1986; Matthews et al. 1990).

We believe there may be a higher long term PIT tag mortality in the wild than has been observed in hatchery studies. our first indication of this was that parr-to-smolt survival rates we calculated from PIT tag detections were lower than expected. In addition, our trap tenders observed previously PIT-tagged fish coming into the traps dead or dying. To determine if there was a problem with long-term PIT tag mortalities, we used our trap recaptures of PIT-tagged parr in an adjusted Peterson mark recapture analysis to estimate the summer parr populations. In all trap data analyzed (fall 1988 to fall 1990), the number of chinook recaptures were large enough (except for fall 1988 Sawtooth trap) to avoid serious statistical bias (>4), and the population estimates were from 1.6 to 6.8 ($x$ = 3.7) times greater than the snorkel count estimates. We believe this indicates a serious error in the assumptions that marked and unmarked fish suffered the same mortalities. Two other factors may be contributing or causing error with this assumption. First, the fish may be loosing the tags in significant numbers. Second, if a tag is cracked during implantation, it will fail when body fluids seep into the tag. Hatchery studies with chinook parr (Prentice et al. 1986; Kiefer and Forster 1990) did not observe significant mortalities, tag loss, or tag failure.

If PIT tags are underestimating parr-to-smolt survival in the wild, it is a serious problem for fish management agencies and needs to be addressed as soon as possible. We are planning a series of field tests to determine if there is additional mortality, tag loss, or tag failure. Our approach will be to block off a side channel in each study area during August. We will snorkel each of the side channels three times to get an accurate estimate of the chinook parr population present. We will then seine and electrofish until we have captured approximately 67% of the population. We will then anesthetize and fin clip (upper caudal lobe) 33% of the population and PIT tag and fin clip (lower caudal lobe) another 33% of the population.

Our trap tenders will walk the section every day (morning and evening) and collect any mortalities observed. In late October, we will seine and electrofish each section until we are no longer capturing significant numbers of fish. We will check all fish collected for fin clips and will scan them with PIT tag and coded wire tag detectors. The coded wire tag detectors will detect non-functional PIT tags in the parr. With this study, we hope to determine if there is significant mortality, tag loss, or tag failure with PIT-tagged parr in the wild during their summer rearing phase.

## Spring Emigration

Contrary to what we expected, smolts from the USR began emigrating in significant numbers before smolts from CR during the two years we have data for (1989 and 1990). We had hypothesized that since CR is lower in elevation and has earlier increases in discharge and water temperature that the smolts would begin emigrating earlier. However, in the past two years, 50% of the chinook smolts from USR emigrated by March 30, 1989 and April 3, 1990, whereas from CR, the dates were April 11, 1989 and April 17, 1990. A possible explanation for this is the greater distance to travel to the ocean may have selected for stocks that leave earlier from USR. In 1991, we will begin to operate the Sawtooth weir trap before the Crooked River trap to make sure we are not missing part of the USR run.

The data suggests that we may have missed a major portion of the steelhead smolt emigration and possibly some chinook from CR in spring 1990. The smolt emigration curves in 1990 suggest that smolt emigration may have continued in significant numbers past late May when we have ended our trapping operations. Steelhead smolt production estimate data indicates we may have missed a significant portion of the steelhead emigrants. These estimates indicate more steelhead smolts were produced than both fall 1989 and spring 1990 steelhead emigrants combined. This apparent extension of the spring smolt emigration from CR did not occur in 1989. In 1991, we will continue to trap until mid-June in CR unless trap data indicates that smolt emigration is complete.

Chinook, steelhead, and sockeye/kokanee smolts apparently key in on the same stimuli for springtime emigration (Figure 3). The data suggests that the approach of major storm events may be the most important stimulus for springtime emigration (Figure 10 and 11). Starting in spring 1991, we will collect daily barometric pressure data during our emigration trapping season to determine if there is a correlation between rapidly falling barometric pressure and increases in smolt emigration.

Steelhead data indicates that in 1989, there may have been significant steelhead parr production in small USR tributaries that we do not currently sample. The main evidence of this is that emigration totals were about equal to our August snorkel count estimates. Either summer 1989 to spring 1990 survival was amazingly high, or significant production occurred in smaller tributaries. In August 1989, while collecting parr for PIT tagging, we observed significant steelhead populations in lower Huckleberry Creek, one of the smaller tributary streams we do not currently snorkel. During winter 1992, we will evaluate the 1991 data and determine if we need to increase our snorkel count efforts in USR to determine parr production from smaller tributary streams.

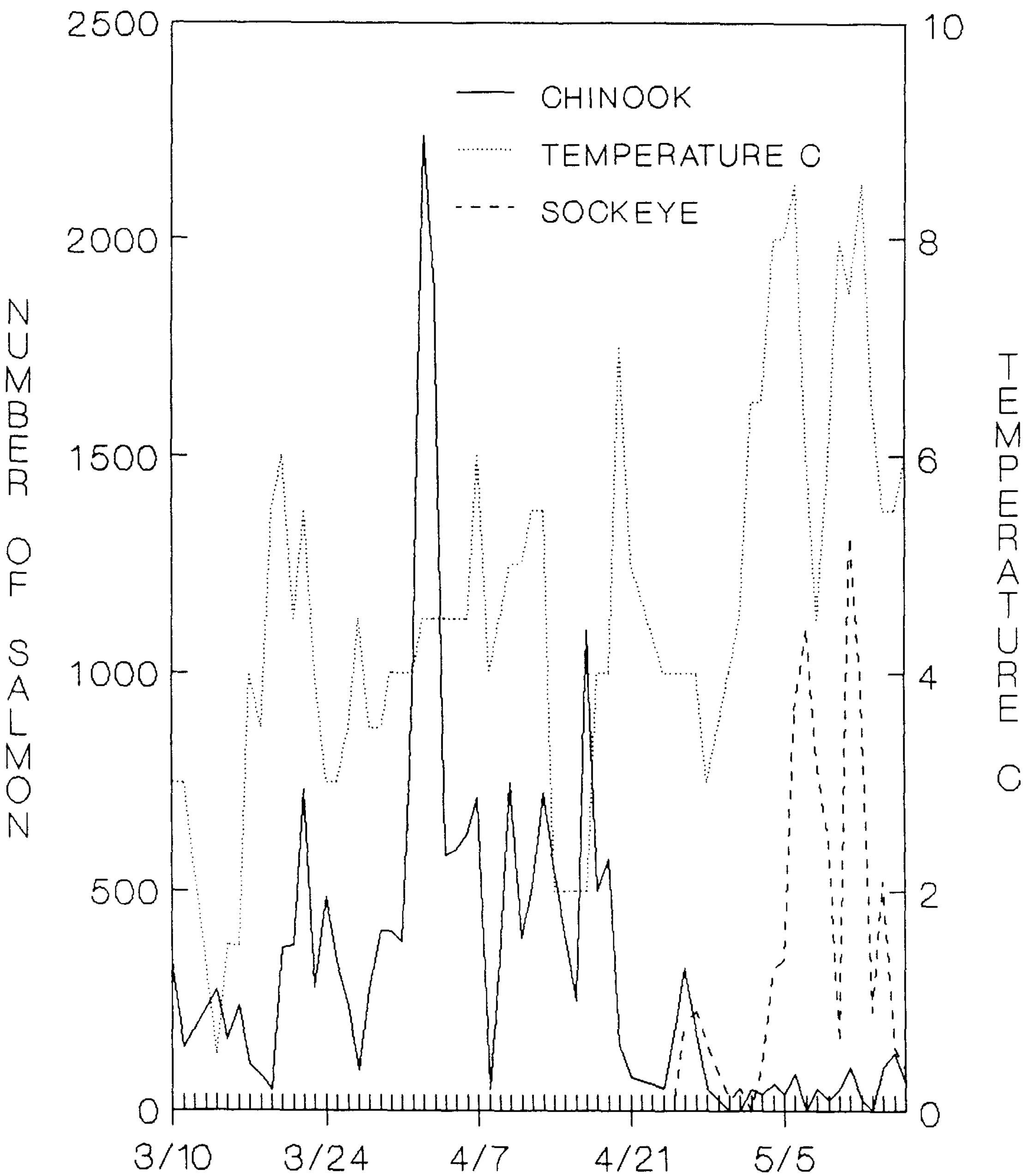


Figure 10. Spring 1990 upper Salmon River chinook and sockeye emigration timing and 10:00 a.m. stream temperature.

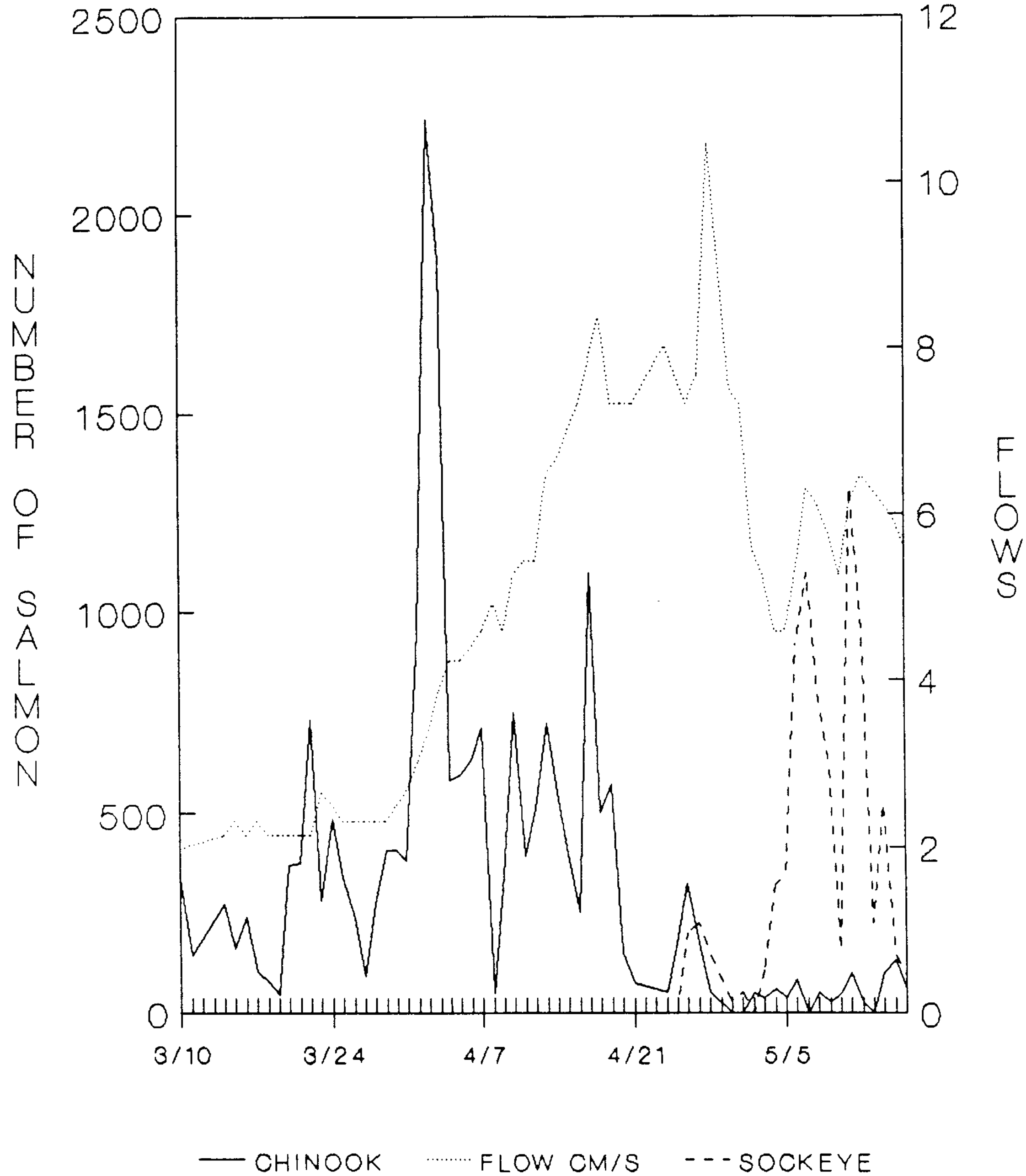


Figure 11. Spring 1990 upper Salmon River chinook and sockeye emigration timing and flows (cms).

## Fall Emigration

Our data indicates that higher elevation (harsher climate) streams will have a higher percentage of parr emigrate in the fall. The 1988 to 1990 averages of chinook and age 2+ and older steelhead parr emigrating in fall from CR were 15% and 17%, respectively, while both chinook and age 2+ and older steelhead from the USR averaged 62%. In both study areas, fewer age 1+ steelhead emigrated in the fall than age 2+ and older steelhead, and a higher percentage of age 1+ steelhead emigrated from USR (14%) than from CR (5%).

In fall 1990, a higher percentage of all parr groups (except CR chinook) emigrated than in the previous two years, and the percent of CR chinook were close to the highest. If the availability of suitable overwinter habitat was the key, then we would have expected lower percentages because the parr populations in 1990 were much lower than the pervious two years. One possible explanation is the natural fish are more likely to emigrate in the fall, and with the large reduction in supplementation for 1990 parr, the overall percentage of fall emigrants increased. Another possibility is that the fish may be responding to environmental cues indicating the potential for a harsher winter in 1991.

As in the spring emigration, it appears that both chinook and steelhead key on similar stimuli for emigration (Figures 4 and 7). Our data suggests that spring emigrants begin moving just before the arrival of storm events, whereas emigration during the fall appears to cue predominately on sharp drops in water temperature (Figures 12 and 13).

Our data also indicates that CR has a well-defined period of fall emigration, whereas in the USR, the fall emigration is more drawn out and variable (Figures 4 and 7). In fall 1991, we will begin operating the Sawtooth weir trap two weeks earlier than we did in 1990, and possibly extend trapping until the middle of November.

## Dam Detections

Detections of PIT-tagged smolts at LGR Dam allows us to determine migration characteristics of chinook and steelhead smolts from both study areas. As in previous years at LGR Dam, the majority of the total chinook run (predominately hatchery fish) arrived earlier than the natural fish from CR and USR (Figure 14).

Unlike 1989, CR and USR chinook smolts had very similar timings of arrival at LGR Dam (Figure 15). This may be a result of the USR chinook being delayed in LGR pool because flows at LGR Dam were reduced to the mid-40 kcfs range during the middle of May when they normally arrived at LGR Dam. When the flows finally increased in late May, PIT-tagged chinook from both study areas were detected in large numbers for a few days (Figure 15). This suggests that the chinook smolts from both study areas were delayed until the flows increased. Detections of wild/natural spring chinook PIT-tagged by NMFS in other Idaho streams also showed this same basic pattern of arrival at LGR Dam (Steve Achord, National

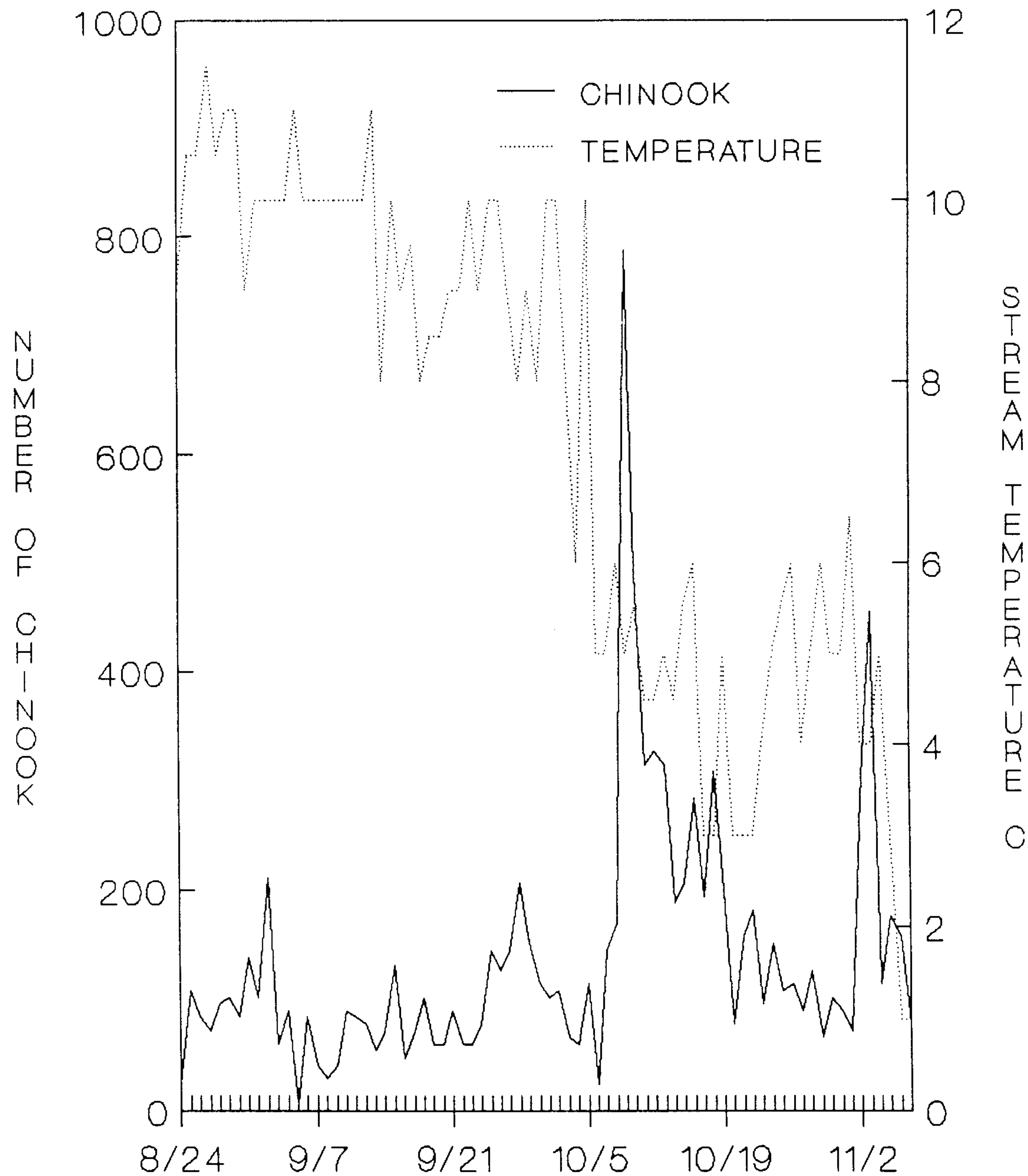


Figure 12. Fall 1990 upper Salmon River chinook emigration timing and 10:00 a.m. stream temperature.

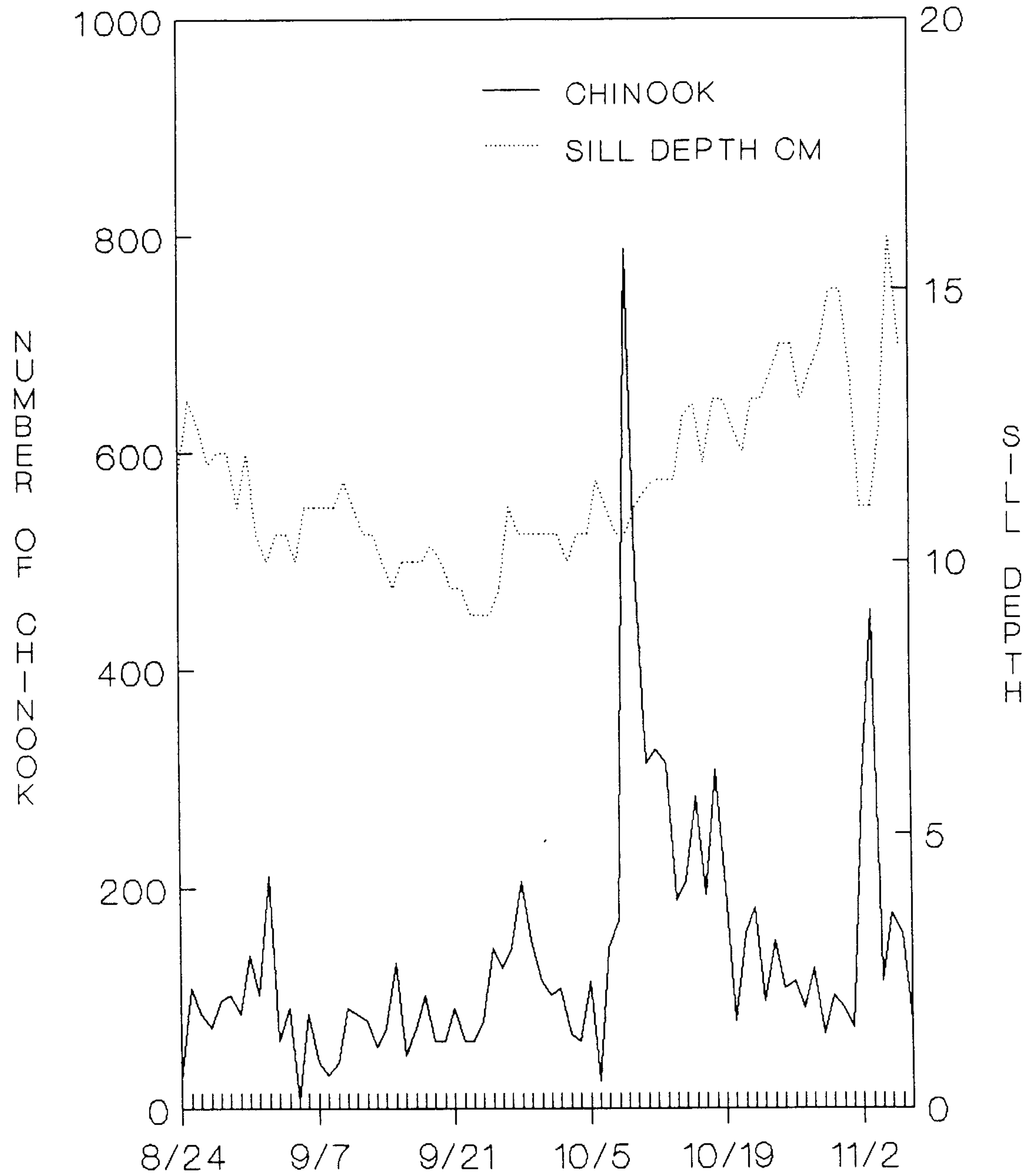


Figure 13. Fall 1990 upper Salmon River chinook emigration timing and 10:00 a.m. sill depth.

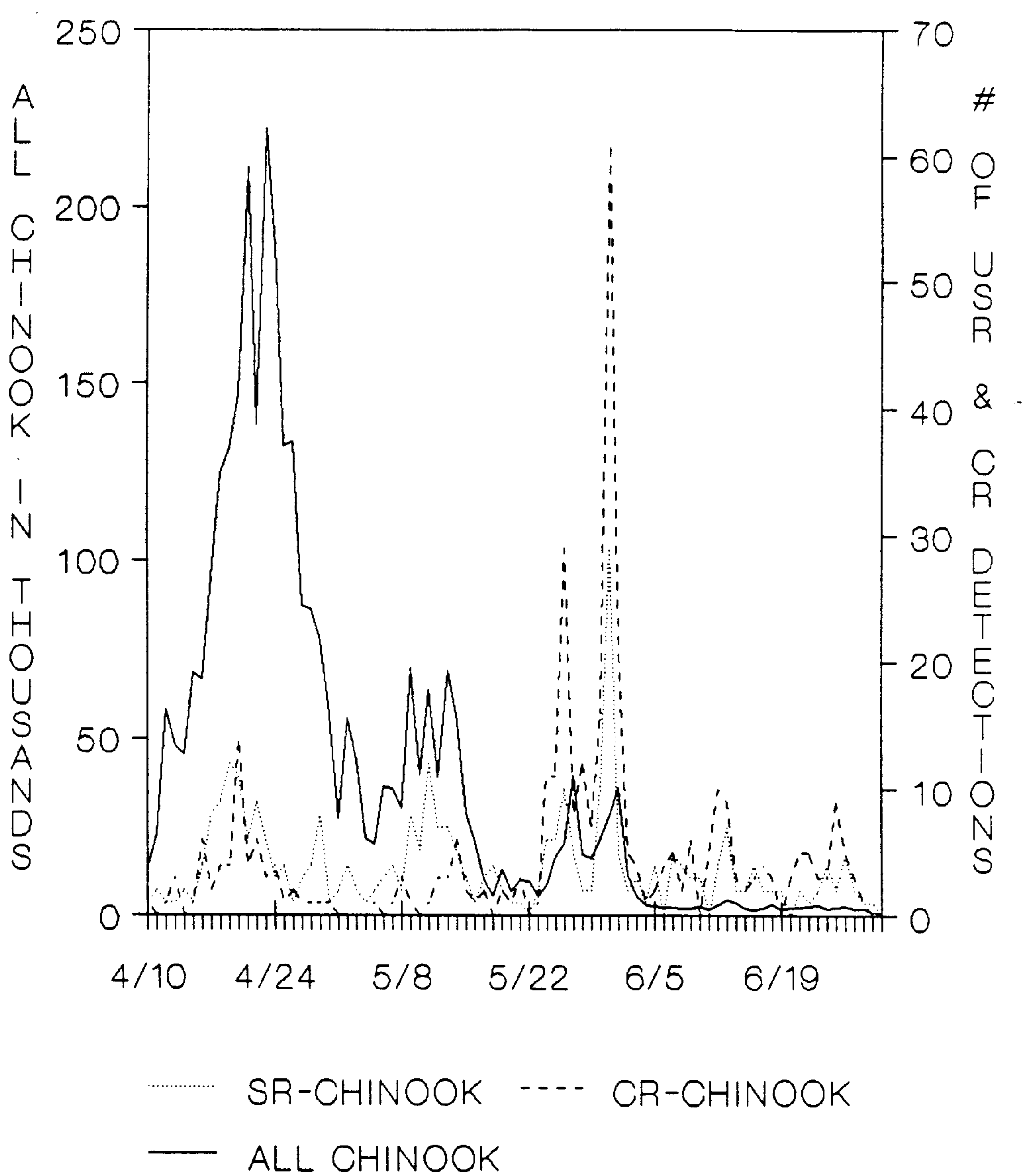


Figure 14. Arrival timing at Lower Granite Dam of all chinook and PIT-tagged chinook from the upper Salmon River and Crooked River, 1990.

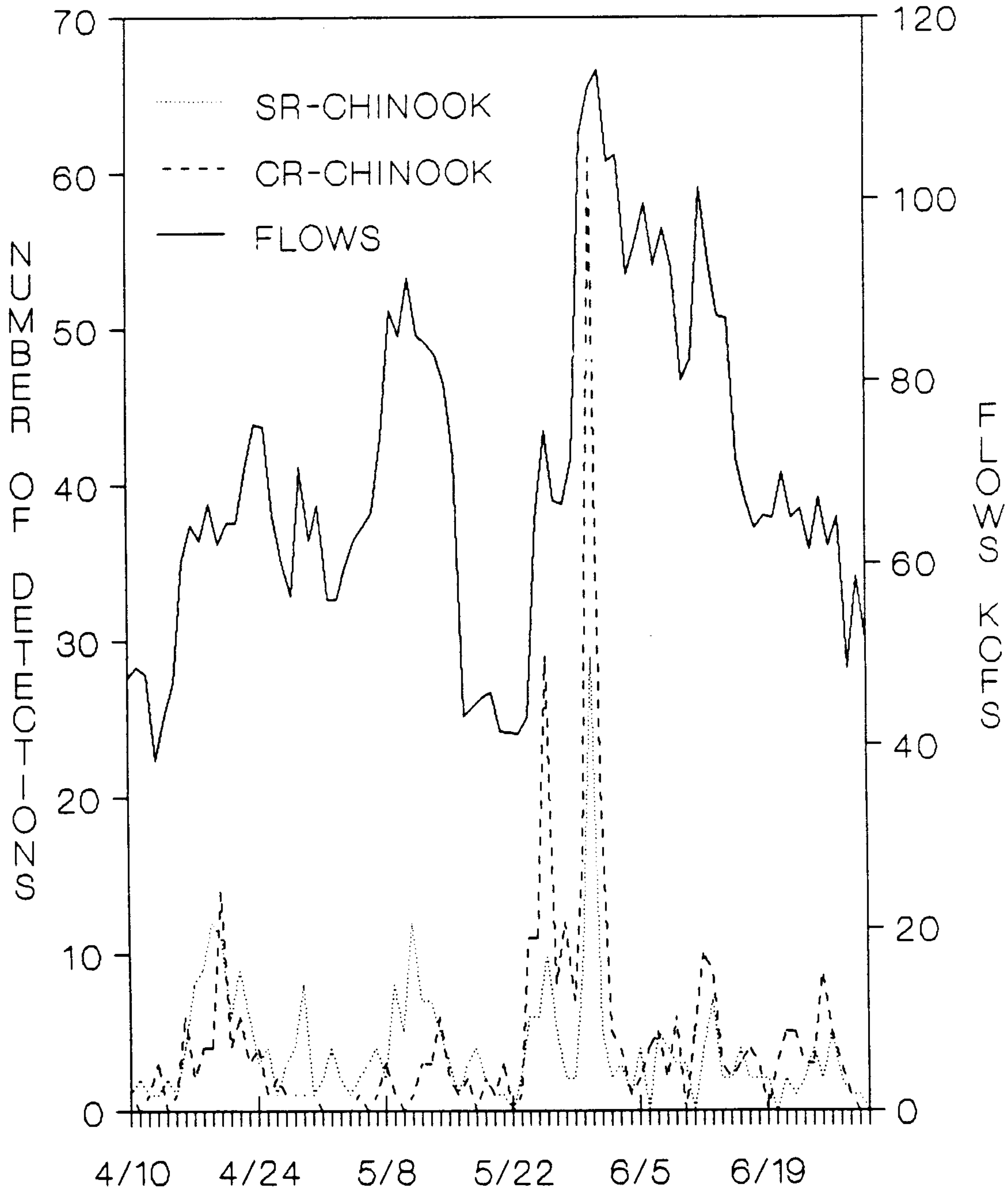


Figure 15. Spring 1990 Crooked River and upper Salmon River smolt arrival at Lower Granite Dam and flows (kcfs).

Marine Fisheries Service, personal communication). This indicates that the wild/natural chinook from the upper Snake River were delayed in LGR pool until unusually heavy spring rains increased flows.

As in previous years, the natural steelhead smolts from CR and USR arrived at LGR Dam within the last major peak of all wild/natural steelhead (Figure 16).

In all years studied, increases in flows at LGR Dam corresponded with peaks of arrival at LGR Dam for all PIT-tagged smolt groups. This also suggests that only at the higher flows at LGR Dam are velocities sufficient for smolt migrations.

The detection of USR sockeye/kokanee smolts at a rate similar to USR chinook suggests that they are truly emigrating to the ocean and not just "drifting out" of Alturas Lake. This raises the possibility that if smolt-to-adult survival could be increased, a sockeye run could be reestablished in Alturas Lake.

The indicated lower collection efficiency for sockeye smolts at LGR Dam may partially be a cause for the declines of Salmon River sockeye runs. If this is true, then flows and passage are probably more critical to the recovery of Salmon River sockeye than collection and transportation.

## Survival Rates

Estimated overall egg-to-parr survival rate for brood year 1989 chinook in the USR (2.1%) was below the other four brood years studied (Table 12) and about 1/7 of that observed from other Idaho streams (Scully et al. 1990). With the lower escapement in 1989 and the subsequent reduction in competition, we expected higher survival. Lower egg-to-parr survivals were also observed in headwater adult outplant and natural spawning areas, but not in Sawtooth Hatchery. One possible explanation for the low chinook egg-to-parr survival in the USR may have been that, after four years of consecutive drought, wintertime flows were much lower than normal, and mortality on eggs caused by scour ice was greatly increased.

We hypothesize that at least part of the reason the five-year average of USR chinook egg-to-parr survival (4.8%) is about 1/3 that of other Idaho streams is that uncounted fry emigrate from the study area during the spring. We have observed significant numbers of chinook fry in our fish trap, which has screens with openings too large to effectively capture fry. Beginning in spring 1991, this project will fund a University of Idaho Graduate Study to evaluate the magnitude of chinook fry emigration and their contribution to the smolt run.

Estimated egg-to-parr survival rate for brood year 1989 chinook in CR (15%) was similar to what Scully et al. (1990) observed in other Idaho streams. We have not observed significant chinook fry emigrations from CR with our trap there. Egg-to-parr survival rates for steelhead will be calculable for the first time after the August 1991 parr abundance estimates are made.

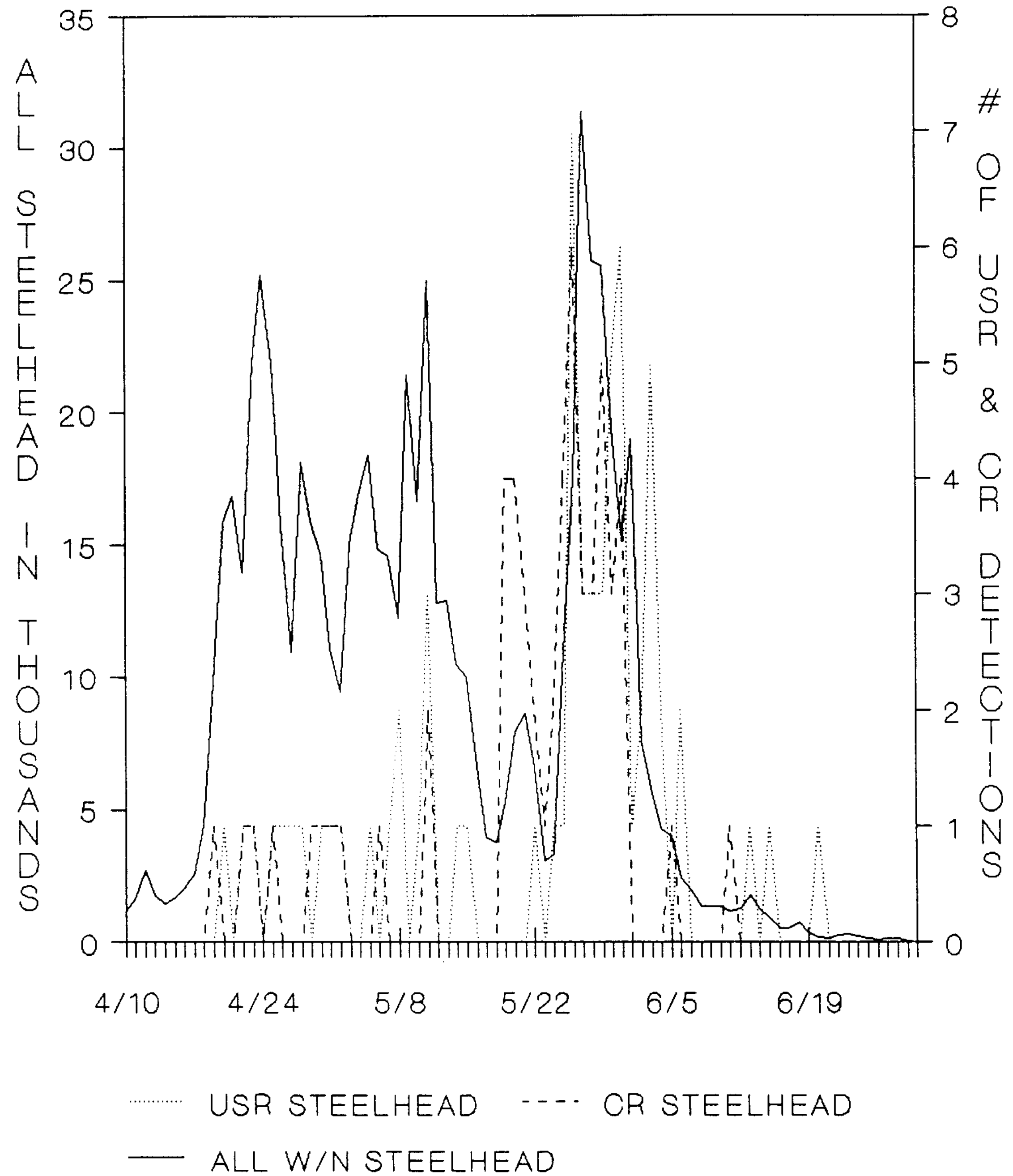


Figure 16. Spring 1990 arrival at Lower Granite Dam of all wild/natural steelhead and PIT-tagged steelhead from the upper Salmon River and Crooked River.

We have consistently observed greater chinook egg-to-parr survival from redds constructed in the headwaters of USR than in the mainstem. Three factors are probably contributing to this difference. First, we believe that the low gradient meandering headwater streams are better juvenile chinook rearing habitat than the predominately fast runs found in the mainstem. Second, we hypothesized earlier that a more natural and successful component of the chinook run is selecting the headwater areas for spawning. Third, we hypothesize that a significant proportion of the fry produced in the mainstem emigrate out of the study area immediately after swim-up.

Our three estimates of chinook parr-to-smolt survival to the head of LGR pool ranged from 6.4% to 9.4% ($\bar{x}$= 7.6%) for USR and 5.6% to 5.7% ($\bar{x}$ = 5.7%) for CR. For age 2+ and older steelhead, the parr-to-smolt survival to the head of LGR pool ranged from 7.8% to 28.5% ($\bar{x}$ = 20.0%) for USR and 6.0% to 14.1% ($\bar{x}$ = 9.0%) for CR. For the two migratory years studied (1989 and 1990), the USR chinook had a higher parr-to-smolt survival than those from CR. This is contrary to what we expected based upon the greater distance the USR parr must migrate. However, we have observed a greater proportion of the chinook parr collected for PIT-tagging from CR having bloated bodies which is an indicator of BKD.

For steelhead, our age 2+ and older parr-to-smolt survival calculations based upon emigrant trapping data may be biased. Our data indicates that on CR, we are not sampling a significant portion of the steelhead emigration, and on USR, we appear to be getting significant steelhead production out of the smaller unstudied tributary streams. These two biases make it appear that the USR age 2+ and older steelhead are surviving at a greater rate than those from CR. However, PIT tag detection rates for all steelhead groups have been consistently greater for CR than USR, and we believe that CR steelhead are truly surviving at a higher rate than those from the USR.

A major objective of this project is to develop adult escapement-to-smolt production curves for both chinook and steelhead. Once the graduate project on the USR determines the proportion of the chinook that emigrate out of our study area, we will be able to develop the relationship between adult escapement and parr production in our study areas at lower seeding levels. With our success with adult chinook outplants, and if enough adults are available for supplementation, we will be able to use adult outplants to define the portion of the curve at middle and higher seeding levels. We expect the results to be a Beverton-Holt type curve for adult escapement to parr production.

When we can at least determine the extent of the bias in PIT tag estimates of parr-to-smolt survival rates, we will be able to develop parr-to-smolt production curves for both chinook and steelhead. We expect the relationship between parr populations and smolt production to be linear at all but the highest density levels. At extremely high density levels, we believe there will be a reduction in parr body condition and a compensatory reduction in the parr-to-smolt survival rate.

If enough adult chinook are available for supplementation at high densities, we should be able within the next three years to develop adult-to-smolt production curves for chinook at both study sites. However, we are not sure if our sample size will be large enough to develop one curve that will be applicable to the rest of the anadromous streams in Idaho.

For steelhead, we do not know at this time if we will be able to successfully use adult outplants to evaluate egg-to-parr survival at middle and high escapement levels. Within the next three years, we should be able to develop the low seeding level portion of the adult steelhead escapement-to-smolt production curve, and the middle to high portions are dependant upon our success with adult outplants.

The chinook parr resulting from natural production in the USR headwaters had a higher estimated parr-to-smolt survival (10.9%) than any other USR group. For the different chinook supplementation techniques we tested during migratory year 1990, we estimated the following parr-to-smolt survival rates: adult 8.5%, eyed-eggs 7.3%, fry 5.7%, and parr 0.8%. The parr outplants tested may have had such a dismal survival as a result of a possible BKD outbreak, possibly made much worse by being outplanted in warm weather.

For the second straight year, the Busterback diversion on the Salmon River apparently did not cause additional mortality to emigrating juveniles. We recently learned that Busterback Ranch released water through the adult ladder on their Salmon River diversion at night. Although this release regime apparently did not improve adult passage, it was most likely responsible for the improved juvenile survival. This diversion blocks adults from reaching the lower gradient headwater streams where we have observed an average of four times the egg-to-parr survival rates than in other parts of the USR study area.

### Smolt Production

The three different methods used for chinook smolt production estimates to the head of LGR pool yielded reasonably precise results for both study areas: CR ranged from 5,709 to 5,811 ($\bar{x}$ = 5,777) and the USR ranged from 9,959 to 14,683 ($\bar{x}$ = 11,922). The smolt production estimates to the head of LGR pool for steelhead were much more variable. We believe the variability in the estimates of steelhead smolt production were probably caused by the steelhead sampling errors discussed in the previous section. Although the estimates of chinook smolt production were reasonably precise, we believe they are probably below the actual production as a result of the biases discussed in the PIT tagging section. Even if we assume that the true smolt productions were four times our estimates (as the mark-recapture estimate suggests), the results are still less than 25% of the Subbasin Plans' estimates of potential smolt capacity (Idaho Department of Fish and Game 1990; Nez Perce Tribe of Idaho 1990).

## RECOMMENDATIONS

1. Data on wild/natural chinook arrival time at LGR, a reevaluation of the current water budget, smolt collection, and transport policies should be considered. The NMFS and our PIT tag detection data from LGR Dam indicates that the Snake River stocks of wild/natural spring chinook smolts arrive at LGR Dam later than the bulk of hatchery smolts. Current water budget decisions are based primarily upon when the bulk of the smolts (hatchery

smolts) arrive at LGR Dam. NMFS and our data also suggest that the water budget procedures in 1990 may have actually further delayed Snake River wild/natural spring chinook smolts during part of their peak emigration period.

Our limited PIT tag data from sockeye/kokanee smolts suggests that LGR Dam is not very efficient at collecting sockeye smolts. We recommend that flows and passage, not collection and transport, would have the best potential to help rebuild the critically low stocks of Snake River sockeye.

2. We recommend continued efforts to reduce stream flow problems associated with the Busterback and Alturas Lake Creek diversions. Our findings indicate this would result in an increase in the smolt production of the USR. Resolution of these flow problems would allow more chinook adults up into the headwaters spawning areas where higher egg-to-parr survival occurs, and allow for better parr-to-smolt survival for those chinook and steelhead parr rearing above these diversions.

3. Additional instream flows should be considered for Pole Creek. During low water years, the water temperature rises above levels optimal for salmonids in Pole Creek between the diversion and the discharge point for the water used to power the Henslee's sprinkler system. Findings show that most salmonids move out of this area to avoid the high temperatures, and those that stay suffer from reduced growth rates. An alternate means to provide electricity to power Henslee's sprinkler system would allow the water now used to power this system to be left in the stream. This should increase the rearing potential of this stretch of Pole Creek and improve the growth rate of salmonids growing there.

## ACKNOWLEDGEMENTS

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Ed Buettner and staff with IDFG - Lewiston Smolt Monitoring Project assisted us with sending PIT tag files to the Columbia Basin data base and with retrieval of PIT tag detection data from the data base. Ed Schriever and Mark Van Stetter assisted us with creel census and chinook redd counts on CR.

Mike Radko and Rick Greter of the Boise National Forest assisted us with our PIT tagging operations in the USR.

Bill Baer and staff with the Nez Perce National Forest allowed us to use a Forest Service cabin while collecting data on CR.

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Ed Bowles and Sharon Kiefer of the IDFG Research Section for their assistance with USR chinook redd counts.

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# APPENDIX

Appendix 1. Catch and harvest estimates for Crooked River, 1990.

| Interval | Effort (hours) | Number released | Total harvest[a] | Steelhead wild/natural | Steelhead hatchery | Cutthroat trout | Bull trout |
|---|---|---|---|---|---|---|---|
| May 26-<br>July 31 | 7,290<br>(±3,099) | 22,553<br>(±8,944) | 6,803<br>(±3,689) | 1,422<br>(±1,541) | 4,290<br>(±2,597) | 594<br>(±571) | 365<br>(±690) |
| August 1-<br>September 30 | 3,205<br>(±2,343) | 12,550<br>(±11,555) | 3,169<br>(±4,196) | 596<br>(±555) | 539<br>(±491) | 1,834<br>(±4.067) | 58<br>(±83) |
| Total | 10,495<br>(±3,886) | 35,103<br>(±14,612) | 9,972<br>(±5,587) | 2,018<br>(±1,638) | 4,829<br>(±2,643) | 2,428<br>(±4,107) | 423<br>(±695) |

(95% confidence intervals)

[a] Includes harvest estimates of 129 hatchery rainbow trout, 88 brook trout, and 58 whitefish.

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